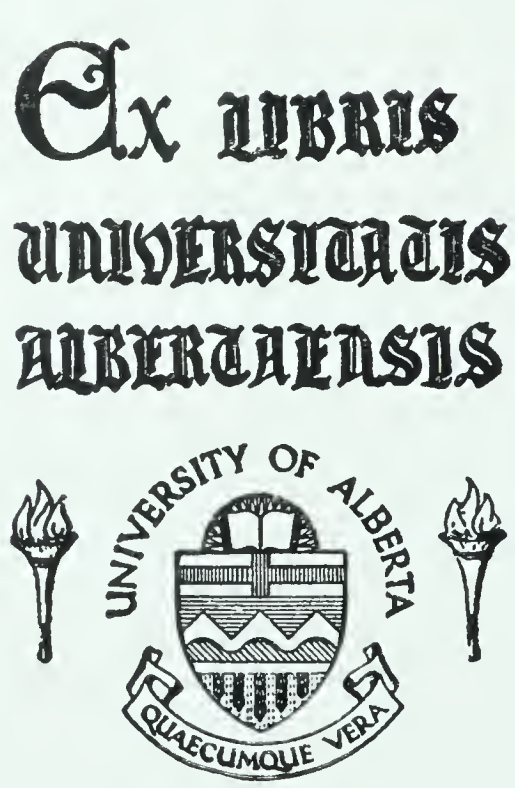
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THE UNIVERSITY OF ALBERTA

ANTHROPOMETRICAL AND PHYSIOLOGICAL OBSERVATIONS ON OBESE AND NON-OBESE YOUNG MEN UNDERGOING A PROGRAM OF VIGOROUS PHYSICAL EXERCISE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

SCHOOL OF PHYSICAL EDUCATION

BY

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EDMONTON, Alberta

July, 1963

APPROVAL SHEET

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies for acceptance, a thesis entitled "Anthropometrical and Physiological Observations on Obese and Non-Obese Young Men Undergoing a Program of Vigorous Physical Exercise" submitted by Jerry A. Dempsey in partial fulfullment of the requirements for the degree of Master of _Science_ _ _ _ .

ABSTRACT

Seven young men, differing markedly in body fat content, were tested at the beginning and end of consecutive periods of: daily training (8 weeks), voluntary training (5 weeks), and daily training (5 weeks). Body composition was assessed by means of water immersion densitometry, skinfold fat measures, and both gross and fat-corrected body dimensions. Basal oxygen consumption, muscular strength, and the Balke treadmill test of sub-maximal work capacity were also measured. Caloric consumption over the entire 18 weeks, and physical activity during the period of voluntary activity, were recorded daily.

The following changes were observed, within the limitations of measurement, in subjects undergoing daily training. Weight losses in initially overweight men were composed of increase in fat-free body weight and muscular mass, and decreases in skinfold and total body fat. One very thin subject increased his gross body weight entirely through a gain of fat-free body weight and muscle mass, while body fat remained constant. These changes were not evidenced during the period of reduced activity.

Total proportional strength increased and decreased with training and detraining respectively, and was not directly dependent upon body mass or body composition. Basal oxygen intake increased per unit of weight and decreased per unit of fat-free body weight. The former change was partially accounted for by an increase in muscle mass, while the latter was attributed, primarily, to a decrease in body fat. Treadmill

performance time improved irrespective of initial values and improvements were retained over the period of decreased activity.

In 36 relatively sedentary young men, five measures of body mass and body composition were found (multiple regression analysis) to account for 52.21 per cent of the total interpersonal variance in treadmill performance time. Relative obesity or per cent body fat accounted for the majority (23.87%) of the variance and was significantly related to performance time with the effect of gross body weight partially out ($r = -.603$). The relationships between these variables were somewhat reduced in subjects who had undergone a daily program of vigorous exercise.

The present findings are in agreement with previous clinical and laboratory observations which have associated obesity with an accumulation of excess body fat as well as sub-normal levels of cardio-vascular performance, muscular strength and basal metabolism. It was further evidenced that a progressive program of vigorous, physical exercise contributed to the therapy of obesity by:

a) specifically or independently changing each of the above parameters, and

b) rendering changes in certain aspects of body composition which in turn contributed to improvements in the selected physiological variables.

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CHAPTER 1

STATEMENT OF THE PROBLEM

Purpose. The general purpose of this study is to assess the effects of consecutive periods of vigorous physical exercise and normal activity on selected anthropometrical and physiological variables in obese and non-obese young men. The indirect appraisal of body composition is limited basically to a consideration of fat and fat-free body compartments, subcutaneous fat, and various gross and fat-corrected body dimensions. Physiological measures include basal oxygen consumption, sub-maximal work capacity and muscular strength.

The specific or independent effects of either physical exercise or anatomical changes on the various physiological variables are investigated through determinations of:

a) the relationships between physiological and anthropometrical changes.

b) the relationship of obesity to sub-maximal work capacity under both sedentary and trained conditions.

Limitations. The major limiting factor in the investigation is the lack of strict laboratory control over the subjects' caloric intake. This factor is diminished somewhat in that subjects are required to tabulate their daily food consumption, which is not restricted, on dietary recall forms after receiving detailed instructions on the use of such forms. This information is not intended to elicit precise quantitative data concerning daily caloric consumption but is employed only as an indicator of any divergence from the pre-experimental caloric intake.

The limiting factors involved in the method of determining total body fat and the fat-free body in a situation whereby changes are rendered through exercise, are discussed in the review of the literature. In order that any changes in muscular mass might be more precisely determined, measurements of fat-corrected limb girths are also included.

The subjects in the longitudinal study comprise a small, select group and can not be considered as a true representation of the male college population. The subjects used in the correlation study are not truly sedentary in that they were participating in a skill-centered physical education program. They must be considered, then, as only "relatively" sedentary in comparison to the subjects undergoing daily training.

The present study is considering the effects of only one particular exercise program on various physiological and anthropometrical parameters. No generalization of results, therefore, may be made beyond these limitations.

Significance of the Problem. Supposedly, physical educators have the professional obligation to develop individualized programs to meet the unique needs of obese children and adults as well as other physically atypical individuals. Whereas there are many statements in professional literature exhorting physical educators to be concerned for the grossly overweight, there appears to be little evidence that this challenge has been responded to scientifically. In fact, it is questionable whether the profession has compiled a valid series of scientific principles upon which to justify or build individualized

exercise programs for obese persons.

Although exercise physiologists have investigated closely related topics, their findings (usually obtained on athletes or "normal" individuals) have only limited applicability while they remain untested in the specific clinical or laboratory situation. The role of exercise in the treatment of obesity is evident, in this regard, as a neglected subject.

The objectives and outcomes of the remedial program are, of course, all important. The cardinal principle underlying treatment pertains to the close relationship which must be maintained between body composition and physical fitness. Such indicators of an unhealthy state as metabolic and circulatory disorders and motor impairment are often attributed to obesity. The solution to these problems must regard cause and effect as inseparable and therefore must be aimed toward the end result of both an optimal state of body composition and an optimal state of physical fitness. Although a few investigators in the nutritional field have analyzed total body weight changes in terms of changes in physical fitness, exercise physiologists have tended to include only one of the variables, i.e., either body composition or measures of physiological performance, in their evaluations of various activity programs. The resulting lack of evidence, in this regard, not only limits the assessment of a particular program, but also leaves many questions unanswered pertaining to the relationships which may exist between variations in body composition and changes, for example, in cardiovascular fitness.

Definitions. 1. Standard weight: Average gross body

weight of persons of a particular sex, height and age.

2. Relative weight: Deviations, positive (overweight) or negative (underweight), of the actual from the standard or "average" weight.

3. Overfat: Positive deviations in the amount of body fat beyond the desirable or optimal.

4. Living obesity tissue (adipose tissue): The tissue gained or lost by experimental overeating or caloric restriction. It is composed (from densitometric analysis) of 62 per cent fat, 14 per cent extra cellular fluid and 24 per cent cellular matter (Density (d) = 0.9478).

5. Body fat (excess): A chemical compound (lipoid), insoluble in water, golden yellow in colour, and with a density of 0.9000 at body temperature. It is stored in fat depots and comprises 62% of living obesity tissue.

6. a) Non-obesity tissue: Body mass less obesity tissue.

b) Fat-free body: Non-obesity tissue plus fat-free mass of obesity tissue: determined by substraction of total body fat from body mass.

c) Lean body mass: Total mass of the body minus the mass of adipose tissue.

7. Active tissue mass: M - (F+B+EW).

M = body mass (kg): F = fat mass (kg).

B = bone mineral mass (kg) (0.07 x fat-free weight).

EW = amount of water in thiocyanite space.

8. Standard reference man (standard body): A suitable standard body is one that is neither fat nor lean. It is the mean of bodies of clinically healthy young men who correspond

exactly to the average weight for height of the healthy population of young men. Standard reference man is: 25.2 years of age, 176.5 cm. in height, 70.6 kg in weight, and a body density of 1.0629.

9. Muscular strength: The ability of an individual to exert a single explosive force against resistance.

10. Circulo-respiratory endurance: The ability of the individual to repeat long-continued contractions (sub-maximal) where a number of large muscle groups are used, with sufficient duration and intensity to place a demand on the functions of circulation and respiration.

11. Basal oxygen consumption: The volume of oxygen consumed under conditions whereby the subject is lying awake and quiet, relaxed and in a state of complete post-absorption.

CHAPTER II

REVIEW OF THE LITERATURE

A considerable quantity of research has been devoted to the measurement and treatment of obesity by investigators in such related fields as physiology, biochemistry, physical education, nutrition and medicine. The review of literature presented in this chapter is aimed primarily towards:

a) an evaluation of various methods and procedures designed for the appraisal of body composition and cardio-vascular efficiency, and

b) a consideration of total body weight change in terms of physiological and/or anthropometrical measurements.

The highly controversial question concerning the effect of various factors on the basal oxygen intake is reviewed in terms of:

a) the relationships found between numerous anatomical variables and basal metabolism, as well as

b) those investigations which have observed variations in basal metabolism as a result of programs inducing changes in body composition.

The role of physical exercise in the promotion of muscular strength and circulo-respiratory fitness has been given considerable attention by researchers, and consequently is reviewed only briefly in this presentation. The relationships found between body mass and composition and the components of physical fitness under investigation are presented in detail.

Body Composition - Appraisal and Definition

Total Body Weight. The popular usage of body weight as the primary indicator of body composition and of such terms as "standard", "relative", and "ideal" weight as meaningful designators of what one "should" weigh, have been subjected to a multitude of criticism in recent writings. The errors committed in methods of measurement and sampling, and in the intended interpretations of "desirable weights" tables (1:6) (obtained from a representative group of individuals of a given height, age, sex, and/or skeletal frame) are thoroughly reviewed and discussed by Gelvin (2:2) and Miller (3:77).

Brozek and Keys (4:246) comment on the term "overweight" by stating: "Since most of the health penalties seem to involve metabolic disorders, diabetes, atherosclerosis, etc., the real question is obesity; i.e. fatness, rather than overweight." This measure of fatness appears as a very complex measure, with the same gross body weight representing, in different individuals, very different mixtures of the basic components - bone, mineral, fat, extra-cellular fluids and cells. The need for complexity is borne out by a comparison of physically active and sedentary men (6:167) with identical measurements of gross body weight, but displaying significant differences in their respective amounts of body fat and fat-free body mass.

Brozek and Keys (4:246) criticize the inability of height-weight tables (even with the inclusion of skeletal dimensions), to differentiate "active" cells from fat.

It appears necessary to distinguish, then, between the

cause of over-weight as being due to an unusual muscular development or to excessive deposits of fat. Variations in body weight may, under specific conditions, serve as valuable indicators of obesity. Keys, et al (7:87), warn of the large amount of variation around the average weight in general populations but concede: "In sedentary individuals, positive deviations from the standard weight are likely to be due to an accumulation of fat rather than muscle tissue and the identification of obesity with marked "over-weight" is largely, though only approximately, correct." Keys' evidence is derived primarily from correlations of weight with fat changes in man.

The evidence, although admitting the necessary inclusion of body weight in the determination of body composition, clearly demonstrates that before it can become a physiologically meaningful variable, it is necessary to know, at least approximately, the value of its components.

The measurement of gross body weight, although apparently simple, may show discrepancies from day to day and therefore confuse the actual picture.

Taggart (8:234) concludes from her review of the rather limited amount of research in this area: "Even with accurate scales and a carefully standarized procedure, the results may be distorted or obscured by short-term fluctuations of weight which are difficult to control because their nature is really not fully understood." The day to day changes appear to be due primarily to "water balance" (8), even in the basal state. All investigators reviewed by Taggart recommended that weight measurements be taken under basal conditions and on

repeated days to ensure greatest accuracy.

Body Compartments. The anatomist has analyzed body composition in cadavers by means of direct chemical analysis. Although this method has been used only sparingly and the normality of the subjects is open to considerable doubt, direct analysis will provide the final calibration data for any indirect analysis.

Brozek and Keys (4:246) state the viewpoint of the physiologist in regard to body composition analysis:

> If we require a system of bodily analysis focused on the total energy metabolism, it is clear that the first distinction is between the metabolically more active part of the body and those constituents that are relatively inert or at least demand little energy directly. Among the latter will be listed, at once, the extracellular fluid, the bone mineral, and the depot fat. To these might be added the horny epidermis, the hair and nails and the excreta, and some secretions not yet discharged. But these bulk small. As a first approximation, the metabolically "active tissue mass" of the body is the gross mass less the extra-cellular fluid, the mineral of the bones and the deposit fat.

This requirement has led, in essence, to the concept of body "compartments" or "partitions" in the appraisal of body composition. Lim and Luft (9:826) define the principles involved in the determination of body density and the estimation of body compartments:

a) the sum of the fractions of the body mass is equal to unity and

b) the total body volume is equal to the sum of the volumes of the compartments.

Behnke, in 1942 (5:495), introduced the concept of lean body mass which was defined as "... a basic mass of lean tissue upon which varying amounts of excess body fat are superimposed." This work also defined excess fat, i.e., body weight minus lean body mass, as "... the storage or depot substance in fat cells." Lean body mass is considered to include a constant small fraction of essential lipoids in the total nervous system and cell walls. Keys and Brozek (4:269) found difficulty in defining Behnke's lean body mass in that "... the amount of fat actually essential to life cannot be determined." Thus the concept of the fat-free body arose, and is considered equivalent, theoretically, to lean body mass less the essential lipoids.

The composition of the lean body mass is assumed to be constant. This assumption was based on earlier studies on tissue electrolysis and body composition in animals and man. The chemical composition of the non-fatty material was found by Murray (10:103) to be practically the same among agricultural animals. A similarity in the composition of the lean body mass was evident for different mammals after maturity from the study of Moulton (11:79), and these findings were substantiated by Pace and Rathbun (12:685), and Spray and Widowson (13:332). The total body water was found to occupy a relatively constant fraction, 71.8 2.9 per cent, of the lean body mass (14:637), and similar values were obtained by post-mortem analyses of presumably normal human corpses (15:596).

In order to determine the amount of lean body mass and excess fat possessed by an individual, Behnke further

developed the method exploiting the specific gravity of the body (5:585). The density of excess fat was given as 0.93 a value obtained by calculation of the density of the tissue lost in one subject during a period of weight loss. The nearer the whole body density is to the density of fat, (.93), the fatter the subject, and those subjects whose density approaches that assumed for the lean body (1.100) are obviously quite lean. By using an appropriate formula, such as the one given by Rathbun and Pace (12:685), an estimate of total body fat could be obtained.

Forbes (17:484) questioned the validity of the lean body mass concept. The author stated: "The fact that individual tissue samples show a high degree of constancy when composition is calculated on a fat-free basis, does not allow one to assume that the total lean body mass does not change as fat is added to or subtracted from the organism."

Very precise measurements of the density of human fat performed by Findanza, et al (18:254), gave an average value of 0.9000 gm./c.c. at 37°C. (4:276). A concomitant increase in the extracellular fluid was also shown in the latter study, and it was concluded that the tissue gained, called living obesity tissue, was composed of 62 per cent fat, 14 per cent cellular matter and 24 per cent extra-cellular fluid. This conclusion has later been supported by Johnston and Bernstein (19:45) and "indirectly" by Miller and Blyth (20:140).

It is thus obvious that living obesity tissue does not consist of pure fat only. It cannot, therefore, be identical with excess fat defined by Behnke as the storage

substance in fat cells. A similar position was defined by Von Dobeln (16:126), who assumed an identity of living obesity tissue and adipose tissue in the anatomical sense, and defined the lean body mass as "... the total mass of the body minus the mass of adipose tissue."

Ljunggren (21:24) introduced the terms "non-obesity tissue" and "obesity tissue" as the two main portions of the body, substituting for lean body mass and excess fat. These concepts seem to be the logical inference of Keys and Brozek since they would allow for the composition of living obesity tissue as well as the constancy assumed for the composition of lean body mass. Obesity tissue is considered, accordingly, as the main variable affecting body composition in adults, whether it be a gain from simple overeating by previously normal subjects or the tissue lost through moderate caloric restriction in obese people (22:486). Non-obesity tissue is, then, defined as the body weight less obesity tissue. Ljunggren concluded further, from a study on small animals (21:53), that the composition of the compartments was constant in normal and obese subjects and independent of sex and different degrees of fatness (21:53).

In light of their findings, Brozek and Keys (4:277), abandoned Behnke's original concept of two main body partitions with definite compositions. In the Minnesota System (23:266), the two body components thus became:

1) the body of a "reference man" (R) defined as a 25 year old individual whose actual weight is identical with the tabular standard and whose density was determined

empirically as d = 1.0629 gm./c.c (6:786) and

2) the tissue gained (G) as a result of simple overeating for a period of six months, with a previously mentioned dG = 0.947 (4:276).

Brozek reasons: "Using these densities in the general densitometric equation, we can calculate the amount (as a fraction of body weight) of tissue similar to "G" that is present in an individual for whom the density was determined (23:225):

$$G = \frac{1}{D} 8.753 - 8.235$$

It was estimated that fat constitues only about 62 per cent of the total weight gain. The fat ($\triangle F$) by which a given individual differs from the reference man may then be calculated ($\triangle F = 0.62G$). Assuming that the reference man contains 15 per cent of his body weight as "fat" (as ether extract), the amount of total fat in a given body can be derived, as a fraction of body weight, by the following formula (4:280):

$$f = \frac{4.201}{D} - 3.813$$

The various concepts pertaining to the composition of body compartments, as interpreted by the present author from the literature, are presented in Figure 1 and Table 1.

The precise calculation of total body fat is not, however, assured. Keys and Brozek (4:280) claim application of their formula "... only over the region of relative obesity-emaciation where gain or loss of weight tends to involve a mass of relatively fixed composition - what is termed "obesity tissue" here." Where dietary weight gain is beyond the point where fat gain exceeds 25 per cent of total body weight, the

authors are unsure of the "gained" composition, but offer the opinion that the composition of the "obesity tissue" will remain relatively constant. With loss of weight (during caloric restriction), below the 10 per cent level, more and more cellular matter is lost, being replaced by extra-cellular fluid, while the loss of fat becomes a smaller and smaller fraction of the solids lost from the body. This occurrence is made evident by the results of the Minnesota Starvation Experiment (7:134). The maximal error in calculations with the extremely emaciated is reported (4:281) to be of the order of two per cent of the gross body weight.

Yuhasz, (24:88), in studying heavily muscled collegiate wrestlers during training, discovered that the total change in fat (as determined by Keys' formula) was not discernable as it was masked by the changes (increases) in muscular weight.

Body Density: The direct chemical analysis of the body involves technical and legal complications besides a formidable analytical task and has been done very rarely. Body density measurement has become a widely used indirect method for the in vivo determination of body "compartments". The density of the whole body is simply the total body weight in air divided by the total volume, i.e., density is the mass of a substance per unit volume (4:267). Using the principle of Archimedes, the volume of the body is determined, through hydrostatic weighing, from its displacement of water - the difference between the weight in air and the weight completely submersed in water being the weight of the displaced volume of water.

If fat has a density lower than water it should

FIGURE 1

ANATOMICAL DEFINITIONS OF THE CONCEPTS

OF THE FAT FREE BODY AND LEAN BODY MASS

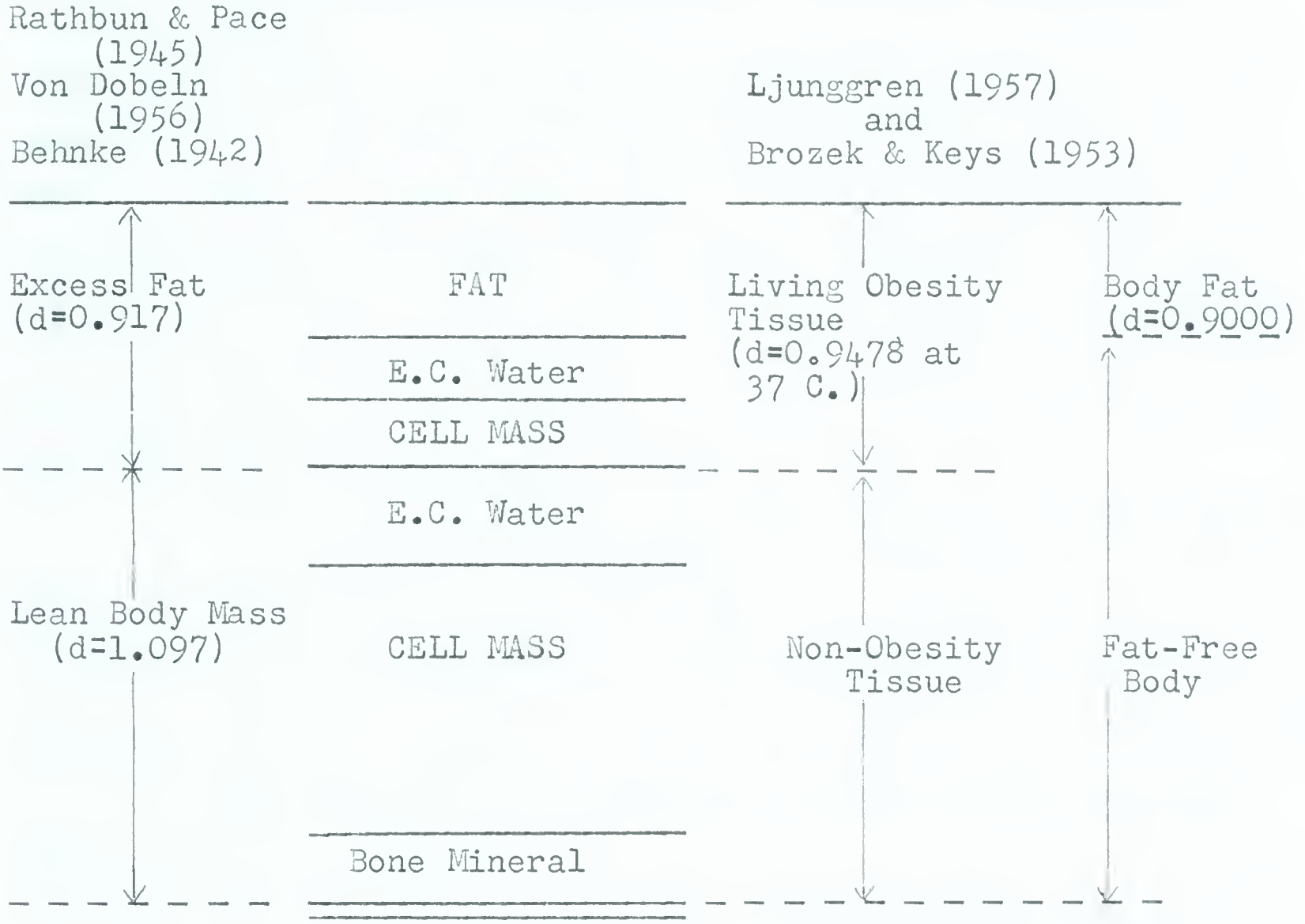


TABLE 1

BODY COMPOSITION FROM DENSITOMETRIC ANALYSIS
OF LIVING OBESITY TISSUE AND THE NORMAL REFERENCE MAN

	Normal Reference	Living Obesity Tissue
Pure Fat	14%	62%
Water	61%	14%
Cell Solids	19%	24%
Bone Mineral	6%	---

Keys and Brozek (9:826) determined: 1) the density of the "standard body" of 25 healthy men, with an average age of 25 years and 2) the density of "obesity tissue" gained by experimental overeating.

float, whereas the fat-free mass, having a density greater than water, should sink, i.e., the larger the proportion of fat, the lower will be the density of the whole body. Welham Fern and Behnke (5) initially evoked this concept by showing that two groups of men, with similar amounts of fat but differing in gross body weight by 50 pounds, displayed identical measures of density, "... the chief difference between the two being body mass, not fat." Wells, et al (25:35), recently supported this original finding and state: "Percentage variations of specific gravity in lean tissue and bone are small and for all practical purposes constant; excess fat is the prime factor governing the specific level of gravity."

In order to eliminate the effect of the variable amount of air in the lungs, the gross volume under water must be corrected for the residual air in the lungs and respiratory passage, i.e., the weight of the water displaced by residual air.

The formula, as presented by Brozek and Keys (4:268), thus becomes:

$$Db = \frac{Ma}{\frac{Ma - MW}{Dw} - Vr}$$

(for measurements taken with the subject at maximal expiration)

(Ma = Man in air; M'w = apparent weight submerged; Dw = water density; Vr = weight of water replaced by residual air)

The residual volume (or the functional residual volume) can be measured in either an open or closed spirometer circuit. In the closed-circuit method, hydrogen, or more commonly, helium is added to the air in the spirometer, and its initial concentration in the spirometer is recorded. The subject re-breathes in and out of the system until complete equilibrium of

of the foreign gas has occurred between the lung and the spirometer, that is, the gas concentration is uniform throughout the lung-spirometer system.

Various investigators have used either "normal" absolute values or certain calculated percentages of vital capacity for the prediction of residual volume (26:19). Keys, et al (4:273), report, however, that by assuming an average value for residual volume, an "uncertainty" (standard deviation) of about 500 ml., corresponding to an error in fat estimation of ± 4% of the total body weight, will result. These authors have also determined the accuracy of the "direct" method and claim prior verification of their results from Carlson and Chen (1953) in concluding (4:272): "The accuracy of residual air measurement by current methods is not an important limitation in the accuracy (± 0.8%) of the densitometric estimation of body fat."

Elaborate apparatus has been devised (27:243) for the determination of residual volume with the submerged subject, due to the possible compressive effect of water on the chest and abdomen. The only documented comparison of submerged and "land" residual volume measurements (27:245) revealed, however, that the underwater values were smaller, on the average, by only 118 c.c., and that this error would result in a lowering of the estimated fat content of the body by less than one per cent. Lim and Luft (9:827) used land determinations of residual volume in determining body density.

Hydrostatic weighing may also be carried out with the subject in a state of maximal inspiration. Howell, et al (28:402), reported greater reproducability of results with this method (r = 0.87) during submersion. When the maximal

inspiration method is employed, it is, of course, necessary to measure the total lung capacity (RV+VC) in order to determine the subject's "true weight" in water.

The lung volume that one should attempt to achieve at the moment of underwater weighing is debatable. Buskirk (23:98) reviews two studies in this area and cites the work of Welch and Crisp (1958) who claimed that the fuller lung was more susceptible to compression on the basis of their findings of higher (+0.0017) body densities with maximum expiration than at one half vital capacity. The author supports the concept proposed by Welch and Crisp (23:99):

> This concept seems to be reasonable when one considers the absolute and not relative change in a small vs. a large volume when exposed to greater pressure. The absolute reduction in the small volume is less than that in the larger volume.

Yuhasz (24) determined the vital capacity spirometrically with the subject submerged to the neck, and provided a verification of this measurement by comparing it with the difference in submerged weights when the subjects had inspired and expired maximally. The largest of the two measurements was considered to be the subject's vital capacity.

Roentgenological studies (4:273, 29) reported "negligible" values (50 - 130 ml.), for denistometric purposes, of gas bubbles in the gastro-intestinal tract. Bedell, et al (30:681), substantiated these findings, with plethysmographic and gastric balloon determinations, finding an average gas volume of 115 ml. Buskirk (23:101 proposed the use of this correction value in the equation for calculating density,

"... in order to provide a more valid estimate of Db on the average."

The question as to the variability of density and the reliability of gross body measurements is answered by Keys' and Brozek's findings: "The net result of consideration of all factors of variability in the normally hydrated body is to conclude they cannot lead to errors more than would be represented by a standard deviation of about 0.005 in the density of ± two percent in the total body weight calculated as fat." (4:274).

Accordingly, it might seem that the only problem is to find generally applicable values for the densities of the body components from which the values of fat and "fat-free" body weight may be determined.

The density of pure fat was mentioned above to be 0.9000, i.e., 1 c.c. of pure human fat at body temperature weighs 900 mgs., and this calculation is substantially upheld in later studies (31). The "obesity tissue" of Keys and Brozek had a density of 0.9478 with the non-fluid gain being a mixture of two components; pure fat (0.9000) and soft-tissue cellular matter (1.06).

Mendez and Keys (31:188) later examined the density of fat-free mammalian muscle cells in dogs and rabbits finding their values to range from 1.069 to 1.079 gm./c.c. at 37 C., which were "... significantly greater than the former estimate of 1.057 for the average of all cells in the body." The density of the fat-free body has been shown to range from 1.077 to

to 1.093 (4, 20). Keys and Brozek (4:271) state that the value of the density of the fat-free body is "... neither known nor in the final sense, precisely knowable." The density found for obesity tissue demonstrates their claim of the fat-free body being only "grossly constant", varying according to the degree of fatness.

Lim and Luft (9:826) state, in their critical review: "Adequate data on the density of the fat-free component of the human body are not available at present and presumably will not be available until the fractional differences in each of the major constituents of fat-free mass; namely, water, protein, and minerals are determinable quantitatively in health as well as in pathologic conditions."

Subcutaneous Fat. The measurement of subcutaneous fat appears as a satisfactory, simple method of estimating body fatness. Approximately half (4, 32) of the body fat lies in the subcutaneous tissue which, in many parts of the body, is only loosely attached to the underlying tissue and can be pulled up between the thumb and forefinger into a fold. Allen, et al (33:352), in devising total body fat prediction standards from skinfold measurements deduced that as obesity, i.e., "... adiposity in excess of 29 per cent of the body's essential mass," increased, the proportion of body fat situated subcutaneously also increased. The authors agree with the approximation of 50 per cent for "normal" individuals but state: "In fat people approximately 2/3 of excess adiposity is located just beneath the skin and in very thin persons, the majority is internal."

The thickness of the skinfold and subcutaneous tissue can be measured by applying some form of caliper to either side of it and the technique has been widely used to give an estimation of body fat. According to the available evidence (23, 31, 34, 35) measurements of the layer of skin with its adjoining tissue made on roentenograms of the extremities do not appear to be more effective indicators of leanness-fatness than the direct (skinfold) measurements.

Edwards and associates (36) carried out experiments to determine the optimal design of a skinfold caliper and recommended:

1) a constant pressure over the whole jaw opening, ranging up to 50 mm.,

2) a squeezing pressure of 10 gms./sq. mm. of jaw face,

3) a scale allowing readings to be taken to 0.1 mm.

Edwards (37) showed high reliability measures at a jaw opening of 7 mm. with the Harpenden Caliper and an average reading of 10 mm. was shown to vary only .5 mm. in 19 out of 20 readings. Yuhasz (24:52) concluded in comparing the Harpenden and Frazen type calipers that the Harpenden gave significantly better (same day) test reliabilities in 8 of the 10 measurements and supported its usage on the basis that it conformed to standards for anthropometric studies in the United States and Britain.

The choice of skinfold sites is determined by the ease and accuracy of measurement and by those sites which will yield

a satisfactory prediction of fat content.

The meaningfulness of skinfold measurements as indicators of total body fat will depend upon the lipoid storing cells in the body taking up fat when the person stores it and giving it up at the same rate when the fat stores are used up. This prerequisite was verified by Edwards (37:268).

The similarity in fat cell distribution in all people of a particular broad age group has also been shown. The distribution of fat appears to differ accoring to sex. Edwards (38) measured 53 sites and found that the normal pattern of females revealed a relatively greater deposition of fat around the shoulders, base of the neck, back, abdomen and thighs than elsewhere, with a "sparing of the extremities." The pattern in adult males was found by Yuhasz (24) to follow one of the greater amounts of fat in the gluteal, supra-iliac, umbilicus and front and rear thigh regions (24).

These and other investigators who have measured subcutaneous fat at various sites with large numbers of subjects agree that although fat assumes somewhat of a general pattern within a particular sex, that marked individual differences, in this regard, are also quite prevalent. Garn (39:89) observed this "individual characteristic" in 13 young men on a program of caloric restriction and concluded: "Fat patterns are permanent and resistant to change in nutritional status." Allen, et al (33:347) conceded from their measurements: "There are slight individual variations and characteristic

sexual differences in the distribution of subcutaneous fatty tissue." The author, however, concluded from further observations that, "... as adipose tissue increases a distinct (group) pattern becomes evident."

Gelvin (2:27) outlines a "descriptive" classification of obesity whereby fat may be distributed in one of four ways:

> 1) about the head, neck and upper body, an accenuation of the masculine configuration; 2) about the lower abdomen, hips and thighs, an accentuation of the feminine configuration; 3) in a girdle fashion with so-called "rolls" of fat about the chin, the axillae, the bust, the abdomen, the hips, the thighs, and in extreme forms, also about the knees. In this form, the overall height of the individual may be short, and the hands and feet relatively small; and 4) generalized obesity, in which the entire body and extremities share rather evenly in the distribution of fat.

Table 11 lists the relationships found between various fat sites and body density and specific gravity determinations (4, 24).

Yuhasz found that the combination of sites numbered 1-6 provided the best combination in meeting the requirements of measurement and in the prediction of per cent total body fat (multiple correlation = .759).

Brozek (23:101) used just three skinfold sites - two locations on the chest and the upper arm in the prediction of body density.

Caloric Restoration, Muscular Activity and Body Composition

Caloric Restriction. "Detailed metabolic studies

TABLE 11

Correlation Coefficients (r) of Subcutaneous Fat Measurements with Body Density and Specific Gravity

Skinfold Sites	Brozek & Keys (1953) (Specific Gravity	Yuhasz (1962) (Density)
1. Abdoninal	.641	.693
2. Chest	.808	.565
3. Sub-Scapular	.648	.624
4. Tricep	.649	.574
5. Supra-Iliac	.678	.659
6. Front Thigh	.608	.602
7. Rear Thigh	----	.597
8. Gluteal	----	.564

demonstrated that human beings do not defy the second law of thermodynamics (the science of the transformation of heat and energy), and that excessive body fat results from an excess of caloric intake over caloric expenditure." (40:1500). Disregarding the relatively minute percentage of obesity cases which might be attributed to "p athological disturbances" or so-called "endogenous" malfunction, the lay and professional population generally recognize positive caloric imbalance as an excessive intake of calories and the obvious remedy is purused.

The important role played by carefully controlled caloric restriction in the treatment of obesity is well established, and the literature reports weight losses as impressive as 366

pounds over a two year period (41:1033) on such a program. The weight loss pattern follows one of sharp loss at the beginning of treatment with gradual reduction as caloric restriction is continued (42, 43, 44, 7).

Loss of subcutaneous fat is similar from individual to individual in that those areas containing larger amounts of subcutaneous fat exhibit an early and marked diminuation in size during semi-starvation. (69,7).

The composition of weight loss has been extensively investigated by Keys (32:25) and he observed:

> The obese person tends preferentially to lose fat on a low calorie diet but even so a considerable portion of his weight loss is water and cellular matter. Severe reduction in food intake in a person who is not fat or extreme dieting to the point of starvation results in an important loss of cellular matter.

Decreases in the fat-free body weight of animals undergoing dietary restriction were reported to be 25 per cent with a total weight loss of 32 per cent (45:299).

The initial twelve weeks of prolonged semi-starvation produced a weight loss of 28 pounds accompanied by a 10 and 8 pound loss of total body fat and "active tissue", i.e., difference between total body weight and sum of thiocynate space, fat and bone mineral respectively. No significant losses were noted in bone material or thiocynate space (extra-cellular fluid) (7:284). The authors observed: "At the twentieth week of rehabilitation, when the total body weight had surpassed pre-starvation level, the mass of the active tissue was still some

8 per cent below the control valve." The active tissues, however, by the fifty-eighth week of "re-feeding" had been restored to values "... very close to those characterizing the men before starvation" (7:285).

Keys (7:135) also reported significant decreases in "... both gross circumferences and muscle tissue", mostly in the thigh and upper arm in the same experiment discussed above.

Brozek, et al (46:419), studied normal men on a daily caloric ration of 1010 calories and found that water comprised approximately 70 per cent of the total weight loss over the first three weeks. The amount of water lost was reduced to a negligible quantity as caloric restriction continued, however, being replaced almost completely by the loss of body fat and protein. The investigators claimed: "Weight loss expected under conditions of a negative energy balance cannot be predicted by considering the caloric deficit alone and by assuming the loss of a certain "tissue" of constant composition, since the caloric equivalent of the loss tends to increase throughout the period of restriction."

The Carnegie Experiment of 1919 extended over a period of 31 days with a total weight loss of 10 per cent from the initial calculations. The results of anthropometric measures showed "... relative changes in the circumference of arms, thighs, and abdomen exceeding the total percentage loss of body weight" (47:277). The investigators did not consider a correction for subcutaneous tissue in recording their girth measurements of the

the limbs.

Keys and Brozek (4:309) state, in an early paper, that dietary weight gain is not a simple matter of adding body fat. They conclude from observations on emaciated men undergoing dietary rehabilitation:

> The proportion of fat to cellular matter progressively rises until final rehabilitation reverses the trend with a loss of fat and replacement with cellular matter, presumably mainly muscle. This latter phase of rehabilitation after starvation closely resembles the change in body composition resulting from increased exercise and physical training in a person previously well fed but muscularly ill-trained.

Brozek, et al (41:420), in a similar study (to that of Keys) observed that during the first days of refeeding following caloric restriction, a rapid gain in weight was due primarily to the retention of water in the body. The authors also stated: "Since the increase of body weight stops or proceeds at a very slow pace later in recovery, in spite of continuing positive energy and protein balances, the storage of these substances must be balanced out by the loss of some of the water retained in the early days of recovery."

Stunkard and McLaren (48:81) recently reviewed the published reports on the out-patient treatment of obesity and found rather unexpected results. Only eight studies met the author' criteria for adequate treatment, i.e., weight was returned to within 10 per cent of the patients' "normal" poundage for his height and skeletal frame, and of these the majority of patients regained their lost weight.

Muscular Activity. The minimal and negligible role often delegated to exercise in the treatment of obesity is amply illustrated by the "opinions" advanced by a medical specialist in the clinical field (2:73). Mayer (49:875) suggests that such claims "... have not been based on recent experimental work or on the accumulated experience of centuries which has always contrasted the lean hard active soldier with the fat merchant or clerk."

The argument that physical activity requires relatively little energy expenditure is not upheld by an examination of the literature. The Canadian Dietary Standards (50) stipulate recommended caloric consumptions for adult men varying from 2900 to 5200 calories per day depending upon the degree of muscular activity.

Keys (51:5) reveals that the proportional energy cost of exercise to body weight no longer applies when the excess body weight is so great that it impairs movement. The possible contribution of activity is highlighted even further by the findings (51, 52, 53) that the rise in energy cost of movement in the obese individual represents a much greater proportional increase than that introduced by the increase in basal metabolism due to excess weight, which is proportional only to a fractional power of gross body weight. Sills (54:41) and Sills and Everett (55:225) demonstrated impairment and inefficiency of movement with obesity, and the subsequent increase following fat reduction in performance on various "motor fitness" test items.

Investigations (56,57) have been carried out to discover the changes in caloric consumption of both animals and human beings as activity is increased. The results definitely cast considerable doubt on the time-honoured conception of exercise as an appetite stimulant and, in fact, suggest a casual relationship with a severe lack of activity.

Mayer (49:880) has compared the obese and non-obese in relation to caloric expenditure and consumption and proposes: "Inactivity is shown not to be the result of extreme obesity but in fact preceded it." These findings are supported in similar studies by Stefanik, et al (58:62), Johnson, et al (59:37), Stunkard (40:1500) and Greene (56:1797).

Stunkard and Pestka (60:815) recently compared the "activity" levels of obese and non-obese girls in a summer camp situation. Pedometer recordings showed only a slightly greater distance (0.9 miles) in the number of miles walked per day by the non-obese controls. A further diagnosis of the situation, however, revealed that all girls were "required" to take part in identical activities at the camp and that the weight losses of the obese girls were significantly greater than their controls.

Passmore (61:692) compared the individual and grouped caloric control methods of obesity treatment and found little success with either approach in their ability to maintain early weight losses. The author recommends, as do other investigators, (49, 62, 63) that increased energy expenditure must accompany the dietary program to ensure long term effects.

Mann, et al (64:349), examined the "motivational"

aspect of exercise in weight control programs and concluded from the comments of their subjects: "Although the first few days of physical training produced discomforts and fatigue, the men soon experienced a sense of well-being and accomplishment that they considered adequate compensation for their troubles." The men in this program also experienced a "... continual loss of fat despite an increase in food intake."

Gordon (65:98) questions the classical interpretation of rising and falling blood "non-esterified fatty acids" (NEFA) levels, (as expressed by Dole, 1956) as being indicative of increased and decreased fat mobilization respectively. Nevertheless, the physilogical justification of exercise in fat reduction seems apparent in that (65:99): "In general, fasting and exercise tend to produce rising (NEFA) levels and administration of carbohydrate food induces a sharp fall." The validity of this observation is substantiated by Guild (66). Sonka and co-workers (67:363) recently studied 63 obese adults undergoing treatments of caloric restriction (1000 calories daily), Fenmetrazin (one to two tablets daily), and muscular activity in the form of sports participation (five to six times daily). The importance of muscular activity is stressed in connection with their findings that:

a) muscular work depressed the activity of the pentose cycle, the result of which was a depression of liposynthesis

b) working muscles utilized preferentially non-esterified fatty acids before glucose

c) muscular activity caused transport-lipaemia from fat depots towards muscles; and this transport lasted for a considerable time following the cessation of exercise.

The authors (67:353) also found a higher activity of the pentose cycle in the erythrocytes of obese people. They stated: "The only known physiological regulation which lowers the activity of the pentose cycle is muscle activity and this phenomenon lengthens the activity of the muscles by one to two hours after the termination of movement."

The combination type treatment resulted in a mean weight loss of 5 to 6 per cent. Neither the initial degree of overweight not the amount or severity of the activity (which was subjectively evaluated) appeared to have a significant bearing on the extent of weight loss. The investigators explained that exercise activates a "hormonal regulator" in the organism which influences the fat metabolism in the whole body, and that the degree of activity need only be sufficient enough for the activation of this regulator.

Keys (32:24-25) has also analyzed body weight and composition changes as a result of vigorous muscular exercise. The major changes involve a decrease in fat and an increase in muscle mass with the variations in total body weight dependent upon the proportional change in these two components. Keys' comparison of programs of caloric restriction and exercise as they affect body composition have been compiled and are presented in Table 111.

Athletes participating in basketball, swimming, foot-

TABLE 111

Possible Composition of the Total Body Weight Change as a Result of Various Dietary Conditions and Exercise

		FAT (%)	CELLS (%)	ECF (%)
Weight Loss	Obese (dieting only)	-75	-10	-15
	Obese (dieting and exercise)	-98	10	-12
	Thin (starvation)	-50	-50	0
Weight Gain	Gluttony alone	66	20	14
	Gluttony and Indolence	109	-20	11
	Intense Physical Training	-38	120	18

(The values are percentages of the total weight change accounted for by fat, cellular matter and extracellular fluid.)

ball, track and field, ice hockey and wrestling (24, 68, 69, 70, 71) have been appraised as to exercise induced changes in body composition. The results clearly confirm Keys' findings of a reduction in body fat and a gain in muscle mass, as evidenced by reported decreases in skinfold measurements and increases in determinations of limb circumferences and/or body density. Total body weight did not change radically in any of the above cases.

Thompson, et al (68:427), comment on the findings of various investigators who have anthropometrically analyzed weight changes in athletes during training:

> It can be concluded from these studies and the present one that body fatness, particu-

> larly subcutaneous fatness, can be altered by strenous training. Concomitant with this change in fatness, body density usually increases even if no loss in weight occurs. Since body cells and body water are more dense than body fat, body density could increase without an increase in muscle mass *per se*. Presumably muscle mass, in certain regions at least, can be increased by training, which lends credence to the usual interpretation of alterations of large muscle groups associated with strenous training.

Studies primarily employing "rhythmic motions", (72:1118) and "endurance activities", (24, 64, 57) in the treatment of "overweight" adult males were successful in significantly reducing total body weight and/or subcutaneous fat.

Howell, *et al* (73), unexpectedly showed negligible changes in weight and specific gravity with various athletes over eight weeks of training. They explained this occurrence on the basis of the subjects' high state of training prior to their respective seasons.

Longitudinal observations (74, 24) on adult males showed reductions and increments in skinfold measurements as the subjects assumed periods of "training" and "detraining" respectively. Once again, the reductions in fat were not always accompanied by decreases in total body weight.

Changes in muscle mass as a result of "progressive resistance exercise" are indiscernable in the majority of investigations due to the failure of the recorded girth measurements to account for subcutaneous fat. The examination of muscle fibre cross-sections in animals (75, 76), however, sub-

stantiates the popularly held concept that skeletal muscle will hypertrophy through exercise employing progressively heavier loads.

The work of Roby (77:275), Tanner (78:459), and Brodt (79), while supporting these findings, reveals the inability of various weight training programs to reduce body fat. These findings logically support the comparatively low caloric expenditure exhibited during "training" sessions (80:151-159).

Cross-sectional investigations on adult males (6, 81) demonstrated a relative maintenance of total body weight along with definite increments in fat weight and decrements in the fat-free mass during the process of growing older. It was concluded by Brozek (16:790): "A decrease in physical activity was the likely principal factor accounting for the observed decrease in the active tissue mass." Behnke, et al (5:500), discovered that, "... an average weight of 200 pounds (with all-American footbal players) is associated with a high value for specific gravity of 1.080." Naval personnel at 150 pounds had the same specific gravity as the 200 pound athletes: "The chief difference between the two being mass (50 pounds) not fat." (5:500).

Keys (51:5) estimated that a change in body weight (as a result of caloric restriction) of 1 kg. represents a change in "stored energy" of about 5,000 calories in the "average" person and about 9,000 calories with the obese patient who is primarily losing fat. For "slightly fat men reducing weight mainly by exercise", an average of 11, 650 calories was lost for

each kg. of total body weight lost. The author thus concluded that the activity group "... was exchanging muscle for part of the fat they were losing."

Wells, et al (25:38-40), in their recent review report on changes in body composition with 12 men undergoing a three week paratrooper training course and with obese girls following four weeks of "intensive physical training." Although the total body weight losses were negligible and even showed an increase in some cases, significant decreases were observed in skinfold fat and abdominal circumferences accompanied by increases in body density and "active tissue." Periods of inactivity resulted in a complete reversal of these findings, as well as a significant gain in body weight.

Roby (77:273) compared changes in subcutaneous fat over exercised and unexercised triceps areas, the results disagreeing with the "... commonly held concept of spot reduction." Thompson, et al (68:42), and Yuhasz (24:69) examined subcutaneous fat changes as a result of various sports training methods at three and ten sites respectively finding that the greater amounts of fat were lost where the most was originally deposited. Schade, et al (82:469). recently compared the effects of six weeks of "generalized" and "spot" (concentrating on the hip and abdominal regions) exercise programs on regional fat accumulation in overweight college women. Although the mean weight loss was "minimal" the waist, hip, and thigh measures reduced significantly. From the analysis of pre and post-training photographs, the authors substantiated previous findings

by concluding: "A reduction in body segments was found where fat accumulation had been most conspicuous."

Factors Influencing Basal Metabolism

Relationship of Basal Metabolism to Body Components.

The use of reference standards and regression equations for the expression and prediction of basal metabolism have recently been critized on the basis of statistical inaccuracy (83) as well as physiological casual relationship." The correlations derived in the process of computing these equations, however, do provide a considerable amoung of insight into the relationships which exist between various body components and basal metabolism.

During the early 20th century, empirical ratio standards for basal metabolism were determined and retain substantial acceptance as "predictors" and "normal" guides today. Dubois and Dubois (86:863) in 1915 derived a formula for the calculation of surface area, and charts (based on Rubner's law (1883) that heat production is proportional to surface area) were constructed for the prediction of basal metabolism. Later investigators established their prediction equations on the significant relationships found between basal oxygen consumption and other gross body measurements such as stature, weight, and/or chest circumference (87, 88, 89).

Behnke, in 1952 (90), proposed using the lean body mass as a means of predicting basal metabolism. The author pointed out that age and sex differences in adults can be accounted for on the basis of variations of excess fat content,

i.e., "... oxygen consumption per kilogram of lean body mass is constant within limits." Other studies have attempted to evaluate the validity of these various concepts by means of determining the relationships between basal oxygen consumption and both gross and the more complex body measurements. (Table 1V)

TABLE 1V

Correlations Between Various Body Components and Basal Oxygen Consumption

	Correlations (r) with Basal Oxygen Consumption					
	References	(16)	(91)	(3)	(92)	(93)
	Measurements	VonDobeln (1956)	Wedgewood (1953)	Miller (1952)	Royce (1958)	Dempsey (1963)
1.	Height	---	---	---	.49	.062
2.	Total Body Weight	.65	.68	.85	.71	.499
3.	Surface Area	.70	.74	.84	.62	.479
4.	Lean Body Weight	---	---	.92	.62	----
5.	Fat-Free Weight	.80	---	---	---	.501
6.	Interstitial Fluid	---	.80	---	---	----
7.	Extra-cellular Fluid	---	.80	---	---	----
8.	Calf Radius	---	---	---	.47	----
9.	Upper Arm Radius	---	---	---	.51	.410
10.	Skinfold Fat	.30[a]	---	---	.42[b] .48[c]	----
11.	Multiple Correlation (2+3+5)	.82	---	---	---	----

a - upper arm site
b - supra-iliac site
c - sub-scapular site

Brozek and Grande (85) and Brozek (94) have presented

critical reviews in order that a frame of reference might be established to determine the "physiological validity" of various reference standards. The authors cite the results of four studies from the German and American literature in which human cadavers were chemically analyzed. They concluded (85:25); "The average amount of muscle in the "normal" adult man is not over 40% of the total body weight and is probably less than that." Their review of 16 direct, in vivo determinations of oxygen consumption from the rates of blood flow and the A-V oxygen differences (94:502) indicate that at rest, the internal organs (notably liver, brain, heart and kidneys) use up over 60 per cent of the total oxygen consumed. The share of the skeletal musculature is estimated at about 25 per cent of the total with a range of uncertainty from about 15 to 26 per cent. Although "... no good estiminate for the share of adipose tissue is available at present", the authors assumed that it could only be a small fraction of the remaining 15 per cent of total basal oxygen consumption not accounted for by the internal organs and musculature.

Basal Metabolism and Changes in Body Composition. Caloric restrictions of varying intensities appear to have a definite lowering effect on basal oxygen consumption as the different aspects of body composition and weight are changed.

Keys and Taylor (53:216) studied subjects on a starvation diet over a prolonged period and found that the basal metabolic rate declined 31.2%, 15.5%, and 19.3% per square metre of body surface and per kilogram of "active tissue" and

body weight respectively. The Carnegie Experiment of 1919 (47) reported a decline in B.M.R. which exceeded the reduction of body weight and surface area.

In observing changes in the basal oxygen consumption the question arises as to how much of the loss is due to the change in metabolizing tissue and how much may be attributed to a change in the rate of metabolism of the changing tissues? Keys and Taylor (53:218) estimate from their data that the greater part (65%) of the B.M.R. decreases in starvations reflects the shrinkage of the metabolizing mass of tissue and the smaller part (35%) should be ascribed to a decrease in the "intensity" of metabolism.

Other studies on much less prolonged caloric restriction (95, 42) show significant losses of B.M.R. with weight reduction but indicate no change when the calculations are based on per kg. of body weight.

Obese subjects were shown by Evans and Strong (7:325) to have B.M.R.s 25% higher than "normal" and this was explained by "... a small but definite oxygen consumption in the fat tissues", and/or the possibility of an overload on the circulatory and respiratory systems causing an increased oxygen requirement. This "metabolic activity" of adipose tissue is further substantiated in the report of Shapiro and Wertheimer (96). The former authors also reported decreases in B.M.R during caloric restriction which were greater than the accompanying weight reduction.

Keys reasoned (7:338) that a reduction in tissue mass

during semi-starvation would affect only the "total metabolism" and attributed a metabolic decrease which exceeded that due to tissue reduction to a severe loss of muscle tonus. An observed decrease in cardiac output per minute of over 50% (greater than percentage of tissue reduction) could also account for a portion of the reduced metabolism per unit of body mass.

A regain of basal metabolic rate during dietary rehabilitation appears to be suppressed. In 12 weeks of recovery from starvation (7:331), the basal oxygen consumption (+30.4%) far out-stripped the increases in gross body weight (+20.1%). However, the basal rate of metabolism per unit of body surface area, per unit of weight, or per unit of active tissue, remained a good deal below the "normal", initial level. Brown and Ohlson (42) followed subjects through much less severe caloric restriction and also provided a rehabilitation period. The authors found little increase in basal metabolic rate during a regain of weight and expressed concern over the ensuing difficulty in the maintenance of a caloric balance.

The importance of actively functioning tissue in energy metabolism has been mentioned previously. Physical exercise, with an accompanying increase in muscular mass, might, therefore, be considered as an influencing factor.

Steinhaus, in 1928 (97:660), revealed, however, that:

> Under the head of influence of muscular work and basal metabolism there have been presented as many different results as there are possible answers. Some claim an increase, some a decrease, a third group believes the basal metabolism remains unchanged.

A review of recent publications dealing with this question reveals that this same disagreement exists today.

Benedict (98) studied men and women after an "active" summer vacation and found no change in the B.M.R. He expressed the possibility of a "fixity" in basal oxygen consumption in a given individual as a result of his findings. Knehr, et al (99), also reported insignificant increases in B.M.R. after six months of distance running. It is unfortunate that neither of these experiments considered changes in body composition, the latter study reporting simply a gain in gross body weight of two pounds.

Lusk and Dubois (100:215) reported:

> After a prolonged confinement in a cage with no loss in body weight, a dog may manifest a marked reduction in basal metabolism. Recovery from this condition is achieved through exercise.

Sheinhaus, (97:670), on the other hand, reported no change in the basal metabolism of dogs with training "... sufficient to put the musculature and the entire organism into excellent physical condition."

Benedict, in a later work (101:88), showed about 5% superior B.M.R. in athletes and males over non-athletes and females respectively. The author commented: "In muscle, oxidation processes are constantly going on and these increases the fuel needs of a person to a very great extent."

Zuntz and Schunberg (74:287) showed an increase of 3.4% and 11.2% in a basal oxygen consumption after 2½ months of marching, despite a "... considerable loss of weight." Cureton (74:293) supports this trend by reporting a 5% increase in

B.M.R. after 10 weeks of "endurance training", and shows an increase and decrease in B.M.R. with training and detraining respectively, over a period of years with adult men. These increases in B.M.R., reported in the latter investigations, coincided with decreases in body weight and skinfold fat and increases in performance on various measures of strength and cardio-vascular endurance.

Cureton also found (74:289) higher than "normal" (based on surface area standards) B.M.R.s for champion athletes, the highest being found with those competing in sports requiring high levels of muscular strength.

Miller (102:46) attempted to explain the "economic principle" of increasing and decreasing muscle mass during training and de-training respectively. The author partially attributes this "natural" occurrence to the correlation of 0.79 ($\pm$0.04) between biceps strength and basal metabolism in a group of 56 men and 58 women between 16 and 50 years of age. Royce (92:70) also observed significant, but considerably lower correlations (r) between basal oxygen intake and strength tests of:

knee extension - 0.40

knee flexion - 0.23

elbow flexion - 0.36

A decrease in basal metabolism has been found with age which between the 20th and 60th years may amount to 20% (101:40). Chaney comments further on a more rapidly diminishing metabolic rate in old age as probably being due "... to the

lessening of the muscle tonus and the slowing down of the body processes." Blunt, et al (103:492), after studying underweight children, reasoned that the frequent finding of a very high basal rate, "... may be due to the relatively high proportion of muscle tissue, the body fat having been depleted early in malnutrition."

Bender (104:130) studied variations in basal metabolism as a result of exercise and analyzed these changes in terms of various physical fitness and body composition determinations. It was found that significant increases in basal oxygen consumption were accompanied by improved performances on the bicycle ergometer and strength tests, decreases in total body weight and skinfold fat, and increases in body density ("vertical flotation" test). The author concluded: "The evidence presented indicates that exercise of the endurance type increases the basal metabolism of the individual by increasing the active, protoplasmic tissue."

Keys and Brozek (4:315) claim that the evaluation of the metabolic situation in both established obesity and in the period of developing obesity is clarified by reference to the active tissue mass. In six months of experimental overeating, the analysis of a 17 per cent weight gain revealed an increase of 12 per cent in total basal oxygen intake but a decrease of 3 per cent in the basal metabolic rate per kg. of body weight. The metabolic rate was only 4 per cent higher than before the weight gain, however, when expressed in terms of per unit mass of estimated active tissue.

The constancy of basal oxygen comsumption per kg. of

of fat-free body weight, among 50 individuals displaying varying degrees of obesity, has been substantiated by the present author in recent findings (93). The use of the "fat-free standard" interpreted the difference between groups varying in their degree of obesity to be almost entirely an anatomical one. The use of weight or body surface area standards, however, indicated a gradual but significant decline in B.M.R. as obesity increased.

Exercise, Body Composition and "Physical Fitness"

Muscular Strength. Muller (105:216) has observed and recently concluded: "Muscular strength increases and decreases with muscular activity and inactivity..." probably due "... to an automatic adaptation to the needs of the job." The author interprets the findings of Petow and Siebert (1925-1928) in stating: "The stimulus necessary for an increase of muscular strength is an increase in the tension, over that previously exerted." These experimental confirmations of the Roux-Lange "overload theory" of 1905 and 1918 originally stressed the necessity for an increase in work "intensity", i.e., work per unit of time. Later investigators devised programs based on this principle and interpreted an increase in "intensity" to mean: a) "progressive loading", i.e., upgrading the weight lifted (106), b) an increase in the "pace" or tempo of muscle contraction (107), and c) "isometric exercise" (105) whereby an increase in strength allows for a progressively greater contraction (increased "tension") against an immovable

force.

Significant gains in static muscular strength over relatively brief periods of time have been demonstrated with both these and various adapted methods by the authors cited above and by a considerable number of later investigators.

A closer scrutiny of the majority of these investigations demonstrates the "individuality" inherent in the ability to increase strength. Hettinger (108) emphasizes the necessity for a consideration of this "trainability" factor - among both subjects and various muscle groups - in all aspects of strength research.

Historical and critical reviews of studies in the field (109, 110, 111), while concluding considerable evidence and unanimous support for programs adhering to the various concepts of the overload principle, clearly demonstrate the lack of agreement in such pertinent areas as measurement, learning, specificity, cross transfer, retention, motivation, and the physiological basis of strength improvement. These authors express general agreement, furthermore, than no real "best method" of strength training has been discovered.

In studies relating body size to muscular strength, it is generally concluded that "lifters" with heavy body weights can lift greater loads than lifters with lighter body weights, but the lighter man is stronger in proportion to his weight. (113).

Jones (112) has estimated that the combined influence of the body build, height and weight factors comprise up to

75 per cent of all factors determining strength.

Orban (113:15) and Rasch (114) found, however, that the body weight - Total Proportional Strength relationship was significant only with body weights under 180 pounds and that the correlation diminished as weight was in excess of this poundage. Sills and Everett (55:227) reported a significant dominance, in dynamometer strength tests, of mesomorphs over ectomorphs due to the "higher degree of muscular development" in the first group.

Wear and Miller (115:630) found that excess weight was a definite handicap in the performance of various motor fitness tests. The authors explained:

> This relationship may be partly an indirect one and factors other than excess weight per se may affect performance. For example, lack of activity, which may be partly responsible for excess weight, would reduce muscle strength and power.

Circulo-Respiratory Endurance. The concept of endurance, while generally accepted as an integral component of physical fitness, is often confused with various types of endurance or "stamina" pertaining to bodily function.

Whereas muscular endurance is "quite specific to the muscle group being used", (116), circulo-respiratory function involves the "total-body mechanisms." Adamson (117:16) has observed: "In activities which involve rapid and prolonged action of large muscle groups, it is circulo-respiratory endurance which will delay the onset of fatigue."

A considerable number of methods have been designed to evaluate circulo-respiratory endurance, including measure-

ments taken in a resting state, during various intensities of exercise and in recovery from exercise. Henry and Hodgson (118:3) state: "The fundamental criterion of physilogical function is the degree of external stress to which the individual can adapt without loss of physiological integrity."

Durin, et al (119), suggest that this "stress" be submaximal in nature and stipulate: "The exercise test should involve large groups of muscles and should be simple to do, the efficiency of the subjects should be high and the work should be measureable." Astrand (120) recommended a test based on gradually increased work intensity if the increase in work is not too sudden and if maximal stress is determined by the work load when a given pulse rate is reached.

Balke (121) designed a progressive treadmill test, which met the criteria mentioned above, and was used to determine an individual's "biodynamic potential." The test involves a progressive increase in slope at minute intervals until the subject's heart rate reaches 180 beats per minute. At this point of "impending exhaustion", Balke claims (122:75) that the time for sufficient ventricle filling between contractions becomes too short as is reflected by decreases in pulse pressure and the oxygen supply necessary to satisfy the requirements of the work load. A continuation of work beyone this point is, in most instances, not paralleled by "further adequate functional adaptation." Work, then, becomes increasingly anaerobic. Balke and Ware (121:677) examined the discriminating ability of many physiological variables for the determination of work

capacity and concluded: "Of all the physiologic functions measured, the pulse rate at any given workload reflected most closely the status of the work capacity of a person." The design of the test is supported by the constancy of treadmill walking mechanical efficiency from one individual to another as well as the high degree of reproducability of test results. (123, 124). Billings (125) substantiates Balke's concept of "impending exhaustion" (at 180 beats per minute) and confirms the finding that heart rate adaptation to each new level of exercise is complete within one minute.

Nagle and Irwin (126:610) justified the use of a heart rate of 180 beats per minute as the termination point for a bicycle ergometer test on the basis that, "... the end point is established by physiological observation and measurement rather than the subjects' will to co-operate."

A report by Johnson and Brouha (127:500) cites the physiological variances of trained and untrained men performing sub-maximal work.

	Fit Man	Unfit Man
Oxygen consumption	lower	higher
Pulse rate during work	lower	higher
Stroke volume during work	larger	smaller
Blood pressure during work	lower	higher
Blood lactate	lower	higher
Return of blood pressure to normal after work	faster	slower
Return of pulse rate to normal after work	faster	slower

Balke and Clark (128:84) showed that 8 to 12 weeks of physical training resulted in a significant increase in treadmill performance time and this improvement was subsequently lost during a period of de-training. These same investigators

studied the "functional potential" of a male subject from 24 to 53 years of age (128:89) finding periods of inactivity to coincide with weight gain and "... low states of condition." Weight was reduced and the maximal oxygen consumption increased as the subject assumed a more physically active life.

Obesity appears to limit the cardio-vascular performance of the individual as previously evidenced by those studies which demonstrated a disproportionately greater increase in energy expenditure as extreme levels of overweight were attained. Buskirk and Taylor (129:78) found that (with sedentary males) the "... presence of fat does not interfere with the over-all maximal cardio-vascular respiratory performance as measured by the Max. VO2 test." The authors added, however, that the extra load "... makes the accomplishment of a specific task more difficult", and that "... the excess fat does increase the oxygen cost and therefore the cardio-vascular load in sub-maximal work." Miller and Blyth (20:140) question the implications to be drawn from the initial findings of Buskirk and Taylor (as stated in the foregoing) by stating: "Since obesity increases the energy requirement of exercise without a corresponding increase in maximal oxygen capacity, it definitely limits the ability to work." Orban and Sklov (130:24) studied the relationship between body fat and the "organic capacity" to adjust to exercise in champion male athletes. The results indicated that although the type of activity in which a person engages is not related to the pattern of fat deposition, one who participates in an activity requiring high levels of organic

endurance such as distance running or cycling, has less fat than one participating in activities requiring less endurance.

Taylor (123:148) partly attributes the superiority in cardio-vascular performance of trained over untrained persons to the increased vascularization in the well-trained muscles. In reference to a previous study (129), this author interpreted a high correlation between active tissue and maximal oxygen intake to be "... consistent with but not necessarily a causal factor in cardiac output." Taylor (123:149) concludes: "The two variables are intimately related in the normal individual and raises the question of whether one (the cardiac output) is not controlled or influenced through some intermediate mechanism by the other (muscle mass)." The author stated in a later study (131:428): "The decline in the maximal oxygen intake during the early phases of semi-starvation reflect principally in a decrease in muscle mass, with the small change in the haemoglobin concentration playing a minor role." Keys, et al (7:689-749), demonstrated, however, that as semi-starvation progressed, the ability to move oxygen to the muscles was further limited by "cardio-vascular inefficiency", increasing anemia and declines in both strength and speed of muscular motion.

Henry and Kleeberger (132) in their study of pulse rate tests for cardiac efficiency considered that body weight played an important role in cardiac response because of the additional work required by heavier persons. Master and Oppenheimer (133) substantiated this concept in reporting a

"linear relationship" between both pre- and post-exercise pulse rate and body weight. Elbel (134) and Elbel and Holmer (135) found an insignificant correlation (r = 0.087) between body weight and post-exercise recovery time and this relationship was similar for pulse rates taken both prior to and during the performance of a two minute step test.

Buskirk, et al (136), conducted a series of experiments to determine the relationship between pulse rate, under varying conditions, and both gross and component body measurements. The first experiment (136:84-86) with 35 clinically healthy young men yielded the following results:

a) the correlations between (densitometrically determined) per cent body fat and absolute body weight (.56) and relative body weight (.67) were statistically different from zero but "... are not high enough individually to reliably predict fat content."

b) the intensity of the association between heart rate and per cent body fat or "relative obesity" was greatest during exercise (r = .59), diminished during three minutes of recovery (r = .463) and was only very slightly related at rest (r = .29).

c) at equal weight and equal work done in walking (the effect of variability in body weight was partialled out), the heart rate was significantly and directly related to the percentage of body weight represented by fat, r (partial) = 0.35). These findings were substantiated in later studies (136:86-87) with both young and middle-aged men. However, a

poor correlation between per cent body fat and the work pulse rate in older men decreased the significance of body fat as a determinant of the heart's reaction to stress. The authors referred to the work of Clawson (1941) in explaining that with increasing age possibly "... general myocardial degeneration is now the more important variable."

Buskirk, et al (136:87) explained that their studies only pointed out relationships and did not imply causulity. This limitation was based on their statement: "General training or general state of physical fitness probably is an important variable since the lean man may be in better physical condition than the fat man and have a lessened pulse increase response for a fixed amount of work." Elbel explains the insignificant relationships obtained in his studies (134, 135) to the fact that his subjects consisted of athletes in training who were in "better than average condition." Master and Oppenheimer (133) used relatively sedentary subjects in their study. Kireilis and Cureton (137:132) found significant negative correlations (-.578 to -.264) between performances of strenuous physical exercises and external fat on the body, the correlations with endurance running being relatively greater than for other exercise tests. Following six weeks of vigorous training on a treadmill, subjects demonstrated significant gains in performance on all endurance tests, along with appreciable decreases in skinfold fat.

Riendeau, et al (23:275), substantiated these high negative correlations between body fat and performance times

in endurance tests. Weight, however, did not "significantly affect" the perfornance of any of the test items, except the 220 yard dash. The author's data (121:684) also illustrates "... the slight handicap of the overweight type who, on the average, had a poor work capacity while the normal and underweight men were somewhat better off."

Kotilainen, et al (138), administered a diet of 800 calories per day over three months which resulted in an average weight reduction of 10.6 kg. for a series of women, and 13.2 kg. for a series of men. The weight reduction was accompanied by a lowering of resting and post-exercise pulse rates. A low caloric diet without loss of weight, however, had no effect on the above physiological parameters. Tuttle (139) found similar results with wrestlers in training who experienced a mean loss of five per cent of their initial body weight as a result of dehydration and caloric restriction.

Once again, no "best" method of (endurance) training is definitely known and there continues to remain many unsolved problems as to the physiological understanding and basis of such training (140, 141).

Cureton (116:3) cites the works of a number of investigators in claiming:

> The best events to develop circulatory-respiratory endurance so far known include: a) steeplechase running, b) continuous muscular endurance exercises done for thirty minutes without stopping, c) interval training in track, running, cycling, swimming, skating, and rowing, d) taking tests in endurance runs, e) cross country running, and f) circuit training.

Alexander, et al (142), however, reported significant increases in performance times on the Balke treadmill test with subjects participating in a very brief (10 minute daily) program of primarily muscular endurance exercises, over a nine week period. Although the subjects' performance times did not approach those achieved by athletes in training, the findings tend to test the tenability of generally accepted concepts concerned with both the prescription of endurance training methods, as well as a definition and complete physiological understanding of the term itself.

Anthropometrical and Physiological Analysis of Weight Changes

The only quantitative study reported in the literature which actually assessed total body weight in terms of physiological and anthropometrical variables is the classical Minnesota Experiment of Keys and co-workers (7). The study took place following the Second World War with the intent of gathering reliable, quantitative information upon which to base an efficient dietary relief program. Thirty two young healthy subjects (mean age of 25.5 years) were restricted to an average daily "semi-starvation" ration of 1570 calories (50 grams protein, 30 grams fat) over a 24 week period, with "no restriction" in physical activity. The resulting data have been compiled and simplified and are presented in Tables V and VI.

Taylor, et al (131), have conducted subsequent in-

TABLE V

Analysis of Total Body Weight Loss in Terms of Body Composition (Minnesota Experiment)

	Weeks of Semi-Starvation	
Anthropometrical Variables	12 weeks	24 weeks
Total Body Weight (kgs.)	-12.11 kgs.	-16.82 kgs.
(% of initial)	-17.4%	-24.24%
Gross Limb Circumferences (inches)		
upper arm	-2.4 ins.	-2.7 ins.
calf	-0.9 ins.	-1.8 ins.
thigh	-2.7 ins.	-3.6 ins.
Corrected Limb Diameters (inches)		
upper arm	-0.6 ins.	-0.9 ins.
calf	-0.5 ins.	-0.6 ins.
thigh	-0.9 ins.	-1.1 ins.
Specific Gravity (gm./cc.)	+.0134	+.0183
Total Body Fat (kgs.)	-5.33 kgs.	-6.95 kgs.
(% of initial)	-55.1%	-71.1%
*Muscle Mass	-15%	-20%
(% of initial)		
Active Tissue (kgs.)	-7.97 kgs.	-10.74 kgs.
(% of initial)	-1.29%	-1.94%

*Muscle Mass - estimated from the average value of the cross sectional area of the upper arm and thigh, corrected for bone.

vestigations at Minnesota concerning the effects of semi-starvation on man. Two groups of young men were studied under the following conditions:

a) one group consumed 580 calories per day for 12 days and the other 1010 calories per day for 24 days.

b) all men ate a diet consisting of pure carbohydrate and 4.5 grams of NaCl daily.

TABLE VI

Analysis of Total Body Weight Loss in Terms of Physiological Measurements (Minnesota Experiment)

	Weeks of Semi-Starvation	
Physiological Variables	12 weeks	24 weeks
Total Body Weight (kgs.) (% of initial)	-12.11 kgs. -17.45%	-16.82 kgs. -24.24%
Basal O2 Consumption (% of initial)	-34%	-39%
Maximal O_2 Consumption (litres/minute) (c.c./kg./wt.)	-1.08 l/min.	-1.41 l/min. -12 cc./kg. wt.
Respiratory Efficiency (c.c of O_2 removed per litre of inspired air)	-9.9 c.c./l	-9.6 c.c./lit.
*Work Capacity (% of initial) (total kg. of work)	-48% -2873 kg. met.	-72% -3794 kg. met.
Strength grip (lbs.) backlift (lbs.)	-24.2 lbs. -73.9 lbs.	-36.8 lbs. -108.46 lbs.

*Work Capacity - from Harvard (treadmill run Fitness Test. Score is calculated from the time of the run and pulse rate recovery.

- The marked deteriorations in both Max. VO_2 and muscular strength occurred between a weight loss of 10 to 16 per cent.

c) assigned exercise (running and walking) requiring 1200 calories per day was performed by each subject.

The 580 calories per day prevented ketosis and demonstrable liver damage but failed to maintain adequate work blood sugar levels. The capacity to perform both areobic and anaerobic work tasks was well maintained but pulmonary

ventilation during work, the oxygen debt and pulse rate responses to a fixed task indicated some deterioration.

No evidence of poor physiological response to the stress of work was noted in the 1010 calories per day group, and "no important changes" occurred in grip strength or the Max. VO_2 per kilogram of body weight or fat free tissue. The total Max. VO_2, however, declined slowly in both groups.

The authors concluded on the basis of these findings (131:421): "When sufficient calories and NaCl in the presence of an adequate vitamin intake are provided to prevent ketosis, dehydration and hypoglycemia, under conditions of moderate energy output, performance capacity is well maintained up to a weight loss of 10 per cent of the original body weight."

The weight loss in the above experiment was accompanied by substantial decreases in body fat, the fat-free body weight, muscle mass and (initially) body water (46).

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CHAPTER III

METHODS AND PROCEDURE

Subjects. The subjects consisted of a single group of seven, healthy, male university students varying initially in their respective amounts of body fat. Fourteen students were individually interviewed and the final group chosen on the basis of availability of time, degree of fatness, and recent medical reports pertaining to the physical health, both past and present, of the individual.

This preliminary screening classified the subjects according to their degree of subcutaneous fat as determined by the summation of measurements taken at three skinfold sites (chest, umbilical, supra-iliac). The total was then applied to normative tables of subcutaneous fat values for male students as compiled by Yuhasz (1:101) (see Appendix), and a general "obesity" classification given to each subject.

TABLE VII

Pre-Experimental Classification of Subjects

Subject	Age	General Description	Subcutaneous Fat Total*(mm.)	Obesity Classification
R.H.	19	first year student	152.8	Obese
C.B.	21	first year student	138.2	Obese
M.G.	18	first year student	129.7	Obese
G.H.	28	second year student	97.9	Fat
L.Y.	22	second year student	61.9	Plump
J.D.	24	graduate student (investigator and instructor)	30.3	Average
M.B.	22	second year student	31.3	Thin

*Total taken from the summation of skinfold measurements, taken at the chest, umbilical and supra-iliac sites.

Procedure. The study was divided into three con-

secutive sections over a period of 18 weeks as described below:

Instructional Phase I. The subjects trained 4-5 days weekly, 50-60 minutes a day over a period of eight weeks. The group met at a stipulated time each day and were under supervision and instruction throughout the duration of the session. Each subject recorded his dietary intake each day.

Non-Instructional Phase II. This particular aspect of the study convered a five week period, both during and immediately following Christmas vacation. The subjects were completely free of supervision or instruction throughout the duration of this period and were geographically divorced from any elaborate athletic facilities or equipment such as those that had been available at the University. Dietary intake and activity participation were recorded daily by each subject.

Instructional Phase III. This phase covered five weeks, with the subjects participating in 40 to 50 minutes of exercise, four times per week. Instruction during this phase of the study was kept to a minimum and the type of activity participation for each subject was entirely elective.

The "fat", "average", and "thin" subjects took part in no regular physical activity outside of the experimental program. The three "obese" subjects were enrolled in required swim classes for beginners, which met twice weekly for 30-35 minutes.

The complete battery of tests was administered on four separate occasions, i.e., at the beginning and end of the

three phases. Total body weight and basal oxygen consumption were measured once every two weeks throughout phases 1 and 111.

TABLE V111

Summary of Test Items

Test Items	Purpose
Gross Body Measurements (3)	To measure total body weight, height and body surface area.
Skinfold Fat (8 sites)	To determine the amount and distribution of subcutaneous fat.
Gross Limb Circumferences (3 sites)	To determine gross circumferences of upper arm, thigh and calf areas.
Corrected Limb Circumferences (3 sites)	To determine changes in muscle mass at the above sites.
Hydrostatic Weighing	To determine body density and thus divide the body into anatomical compartments.
Strength	To determine the strength of each of four muscle groups, total proportional strength and strength per lb. of body weight and per lb. of fat-free body weight.
Balke Treadmill Performance Test.	To evaluate circulo-respiratory fitness for sub-maximal work.
Basal Oxygen Consumption	To calculate the B.M.R. per unit of body weight and fat-free body weight.
Questionnaires (2)	To determine the suitability and background of the subjects prior to phase 1 and to evaluate the exercise program in terms of the subjects' personal reactions.
Inventories (2)	To record daily caloric intake (all phases) and daily activity participation (phase 11).

Appraisal of Body Composition

Gross Body Measurements. 1. Total Body Weight was measured on a standard laboratory scale to the nearest quarter

of a pound. Subjects were nude, in a basal state (12 to 14 hours after eating), and the bladders were empty.

2. Height, standing. The total body length was taken from the soles of the feet to the top of the head. The subject stood barefoot with the feet together, the heels and scapulae in contact with the vertical arms of the stadiometer. The attached horizontal arm of the stadiometer was lowered to make firm contact with the scalp. The height was measured to the nearest quarter of an inch.

3. Body Surface Area (in square metres) was determined by applying the subjects' measured height and weight to the "Body Surface Chart" (nomogram) of Dubois (2:32)

Subcutaneous Fat. Skinfold measurements were taken by the following standardized procedure:

1. A fold of skin was firmly grasped between the left thumb and forefinger and lifted up.

2. The contact surfaces of the caliper were placed approximately 1 cm. from the fingers.

3. The pressure of the fingers was gradually released so that the greater pressure was exerted by the caliper.

4. The scissor grip of the caliper was released by the right hand and, when the needle stopped, the reading was taken to the nearest tenth of a millimeter.

All subcutaneous fat measurements were taken with the Harpenden Skinfold Caliper, with a contact surface of 6 x 15 mm. and a constant pressure of 10 gm/mm^2.

The following sites were measured on the right side

of the body:

1. Upper Arm (2 sites). The sites are located over the triceps and biceps areas at the level of greatest prominence. The level was located with indelible markings when the arm was flexed at 90°. Measurements were taken with the arm hanging freely, the crest of the skinfold being parallel to the long axis of the arm.

2. Subscapular skinfold was measured below the tip of the right scapula, with the subject standing, but relaxed. The fold was lifted along a line about 45° from the horizontal level, going medially upward and laterally downward.

3. Supra-iliac skinfold is located immediately above the crest of the right ilium. The fold was lifted at a slight angle to the vertical along the normal fold line.

4. Umbilical skinfold is located to the left of, adjacent to and in line with the navel. The fold was lifted parallel to the long axis of the body.

5. Thigh (2 sites). The sites are located over the front (quadriceps) and rear thigh areas at the level of greatest dorsal and frontal prominence. This level was located by indelible markings with the foot placed on a six inch bench, hips lowered until an angle of 90° was assumed at the knee joint and muscles contracted. The measurements were taken with the foot placed on a six inch bench, with the knee slightly flexed and muscles relaxed. The fold was lifted parallel to the long axis of the leg.

6. Calf. The site is located at the level of greatest

prominence on the medial aspect of the calf. The level is located with the subject in the same position as was described above for the location of sites on the thigh. The skinfold is lifted parallel to the long axis of the leg with the knee slightly flexed but muscles relaxed.

7. Chest. (juxta-nipple) The site is located above and slightly to the right of the nipple. The skinfold is lifted at a 45° angle to the horizontal with the subject breathing normally.

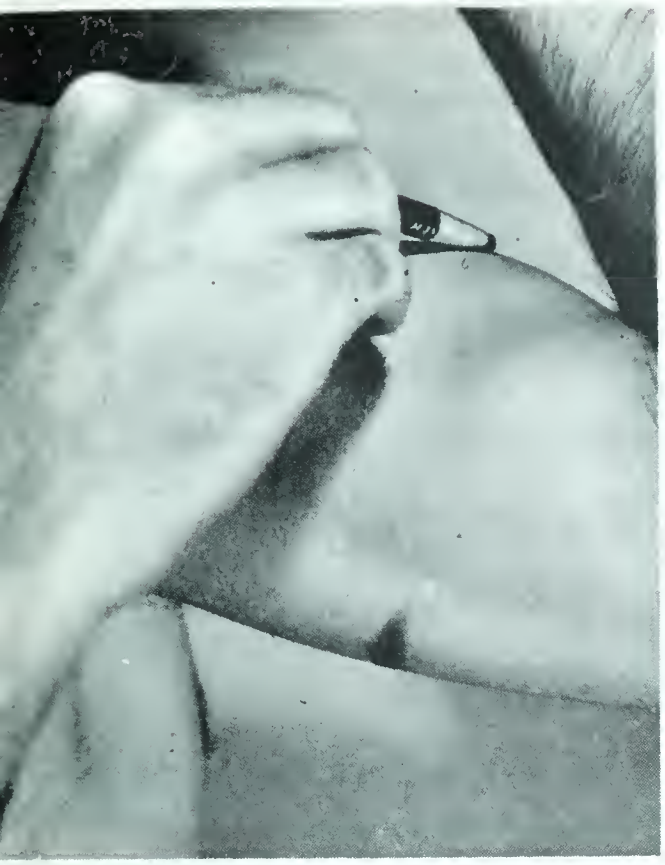
Body Dimensions. Limb girths of the flexed upper arm, thigh, and calf were taken at levels previously described for the location of skinfold fat measurements in these particular areas. The girths were all taken at right angles to the long axis of the limb, with a (Mitchell) anthropometric steel tape which applied a constant tension for all measurements. Measurements were recorded to the nearest one-tenth of an inch.

The limb girths were corrected for their covering of subcutaneous fat by assuming the girth to be circular and that the average of the two skinfolds measured represented the average thickness of the subcutaneous fat about the whole limb. The corrected limb diameter was then obtained by applying the formula as outlined by Brozek (3:17) and illustrated by Yuhasz (1:44) (see figure 11).

In correcting the calf girth, the medial skinfold only was measured. The summation of the three fat-corrected sites was used as an indication of total muscle mass (actually muscle plus bone).

Figure 11

CORRECTION OF LIMB CIRCUMFERENCES FOR SUBCUTANEOUS FAT



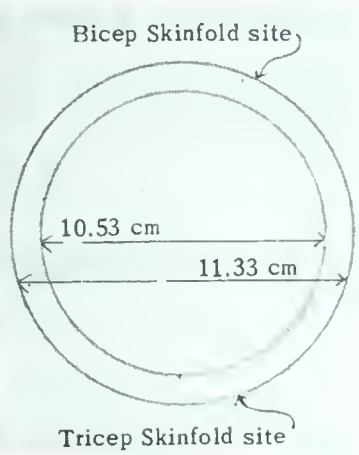
LOCATION OF SITES

Circumference of upper arm - 14.0 in.
Double Bicep skinfold thickness - 6 mm
Double Tricep skinfold thickness - 10 mm

Circumference of upper arm in cms:
14.0 x 2.54 = 35.56 cm.
Diameter of upper arm in cms.:

$$\frac{35.56}{\pi} = 11.33 \text{ cm}$$

Sample Calculation: (Yuhasz-1962)



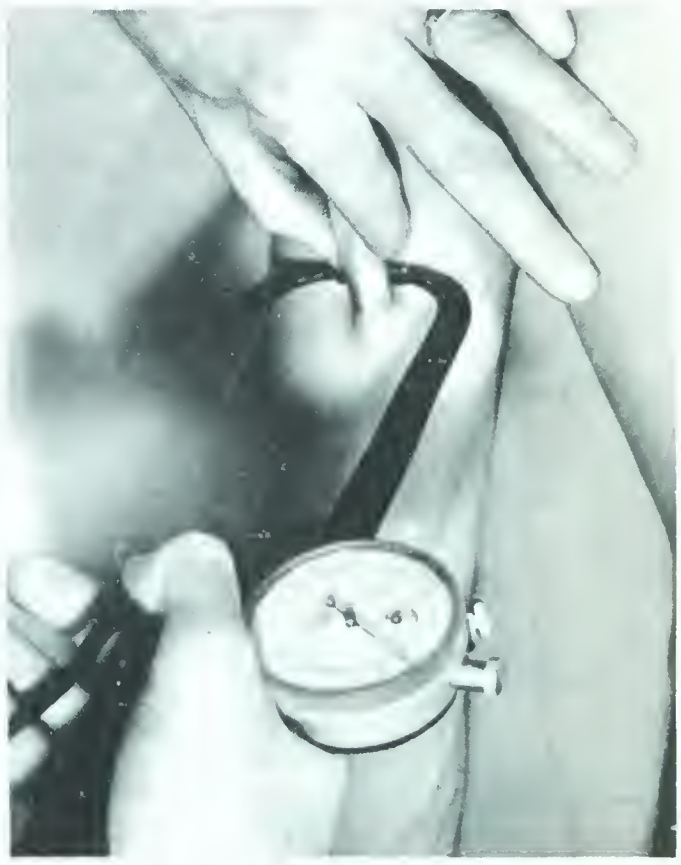


GROSS CIRCUMFERENCE
(Mitchell, constant tension, tape)

Bicep plus tricep fat thickness - 16 mm
Average thickness - 8 mm or 0.8 cm
Diameter of arm corrected for fat:
11.33 - 0.80 = 10.53 cm
Circumference of upper arm corrected for fat:
$10.53 \text{ cm} \times \pi = 33.0 \text{ cm} \times 2.54 = 13.0 \text{ in.}$



FRONTAL SKINFOLD
(tricep)



DORSAL SKINFOLD
(bicep)

The circumference of the abdomen was taken at the level of the umbilicus, and in a plane at right angles to the vertebral column. The subjects stood with head erect, breathing normally and with the upper extremities held slightly away from the body. The tension applied by the tape was sufficient only to enable the tape to remain in place without slipping.

Densitometric Determination of Body Compartments

1. Hydrostatic Weighing Technique. All measurements took place in the diving well section of the University swimming pool. The apparatus used in measurement consisted of the following (see Figure 111).

a) Collins Vitalometer (for Vital Capacity determination).

b) Toledo "No Springs" Scale (Model No. 15594) which was securely fastened to the one metre diving board. The scale was graduated in ounces and the dash pot was filled with heavy (number 20) oil to ensure slow movement of the scale hand for more accurate readings. A regulating device was mounted on the scale which maintained the scale dial at a zero reading until the subject was submerged and in a steady position.

c) Weighted abdominal belt which ensured negative buoyancy on the part of all subjects. The belt was attached, by cables, to a circular metal apparatus which served to keep the cables away from the subject's body, and this apparatus, in turn, was hooked to the bottom of the scale.

Prior to the underwater weighing, the subject's vital capacity was taken while holding on to the edge of the pool and

Figure 111

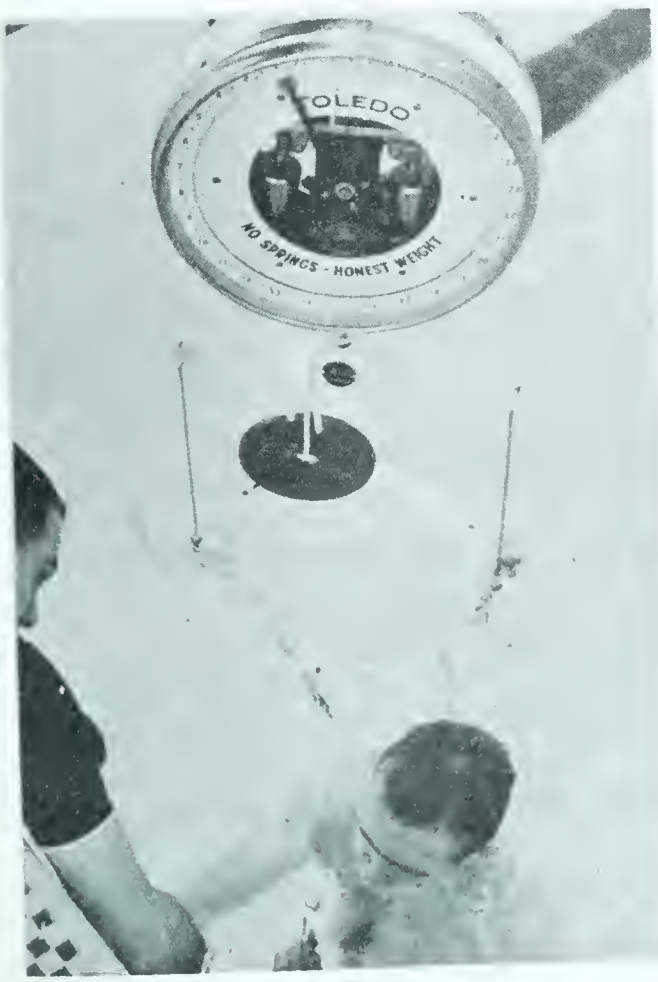
HYDROSTATIC WEIGHING TECHNIQUE



VITAL CAPACITY
(partially submerged)



APPARATUS



SUBMERSION
(maximal inspiration)



SUBMERGED POSITION
(maximal inspiration)

while submerged to the neck. The maximal inspiration of the subject was audible and the highest measurement of four trials was considered as the subject's partially submerged vital capacity.

The apparent submerged weight was determined in the following manner:

a) The weighted belt was secured around the abdomen and the subject slid quietly into the water holding on to the edge of the pool.

b) The subject submerged completely and scrubbed the body to dislodge gas bubbles in the skin and hair.

c) Immediately following a maximal, audible inspiration, (identical to the inspiration for the measurement of vital capacity), the subject was lowered below the water.

d) When the subject had reached a position of full extension (level of abdominal belt was 18 inches below water surface), with arms hanging in contact with the body, the "regulating dial" was turned to activate the scale hand and the reading was taken to the nearest ounce (usually within 5-7 seconds).

e) Following the reading, the subject was immediately touched on the chest with a pole and pulled to the surface.

f) The test was repeated until the lowest measured weight was obtained ($\pm$2 ounces) on three trials. Each subject underwent five to ten "training" trials prior to the initial measurement to overcome fear of submersion and to promote relaxation during the actual measurement.

The subject was weighed with a maximal inspiration. Two readings were also taken, when possible, with the subject in a state of maximal expiration in order to check the spirometric vital capacity determinations. The room and water temperatures and barometric pressure (mm. hg) were recorded at the time of each weighing.

2. Formula: (for measurement taken at full inspiration)

$$\text{Body Density} = \frac{\text{Weight in Air}}{\text{Weight in air - weight in water - 0.0362 (TLC + VGI)}} \times \text{Density of Water}$$

Note - Total Lung Capacity (T.L.C.) in cubic inches was converted to pounds by multiplying by 0.0362.

- Density of Water was corrected for water temperature, which remained constant (27°C. to 28°C.) for all measurements. Example, density of water at 27°C. = 0.99654.

- Lung Volumes were reduced to values under "Body Conditions", i.e., at actual atmospheric pressure, body temperature (37°C.) and fully saturated with water (B.T.P.S.)

- V.G.I. - Volume of gas in the gastro-intestinal tract. An average volume of 115 ml. was assumed for this study as proposed by Bedell, et al (4:664), from plethysmographic determinations.

3. Sample calculations for body density and the body compartments are presented in the appendix. The formula of Brozek and Keys (5:280) was used to determine total body fat from human density:

$$\text{Total Fat} = \frac{4.201}{D} - 3.813$$

4. Measurement of Residual Volume. The total lung capacity was determined on land by the nitrogen dilution, closed circuit technique. Procedures and calculations were based on the principle as outlined by Comroe, et al (6:15-17), (see Appendix C).

The subject was re-breathing from the spirometer at the "more constant" resting respiratory level and the calculation of residual value was thus determined from the measured functional residual volume: R V = functional residual volume - expiratory reserve volume.

Vital capacity measurements were conducted immediately following the attainment of helium equilibrium (in the spirometer and lungs) and the values were taken directly from the kymograph recording and corrected to BTPS.

Testing conditions did not allow for the determination of residual volume while the subject was submerged. The following precautions were taken in order to minimize any error which might result from the possible compressive effect of water on the chest and abdomen:

a) the lung volume measurements on land were taken within a few hours after the subject's apparent weight in water was determined,

b) the "land" measurements were taken with the subject in an upright position, and

c) the volume obtained on land was checked by taking two readings of the vital capacity, i.e., one on land and the other with the subject submerged to the neck. This procedure provided three determinations of the vital capacity (including

the difference between the weight of the submerged subject in states of maximal expiration and maximal inspiration). The largest of the two values (in cubic inches) was then considered as the subject's vital capacity in the calculation of body density.

Measurements of Body Function

Basal Oxygen Consumption (Closed Circuit Method).

All determinations of basal oxygen consumption were carried out on a Collins 13.5 litre Respirometer. The laboratory conditions for testing were as follows:

1) the test was adminstered in a well ventilated, quiet room and a comfortable temperature of 66° F. - 72° F. was maintained,

2) the testing table was comfortably padded and a small pillow and blanket were provided for each subject, and

3) the respirometer was prepared prior to each testing by flushing it out with oxygen and checking the CO_2 absorber (soda lime cannister) for crystal discolouration .

The following routine was standardized for each testing:

1) the subject came to the baboratory between 7:30 and 9:00 a.m. in a post-absorptive state, i.e., 13-14 hours after eating,

2) a rest period of 20 minutes was assigned for each subject followed by a ten minute training session whereby the subject was familiarized with a nasal clip and a mouthpiece,

3) the testing procedure and spirometer mechanism were carefully explained to each subject and he was instructed to con-

centrate on subject matters other than breathing, to breathe only through the mouth and to keep the lips pressed firmly around the mouthpiece,

4) the free breathing valve at the mouth was then closed, "re-breathing" from the spirometer began and a kymograph recording was taken with the drum turning at the slow speed (32 mm. per minute),

5) the test lasted for a period of 10 minutes (minimum) with relaxed, co-operative subjects. If breathing was irregular or interrupted by frequent sighs, spirometry was prolonged until an adequate oxygen base line could be drawn. Repeated trials were carried out on consecutive days if a subject continually demonstrated an inability to relax, and

6) sixty second, brachial pulse rates were obtained periodically throughout the resting, training and re-breathing portions of the test, for the detection of abnormalities or irregularity.

The volume of oxygen uptake was measured by reading directly from the paper graduated in ml. and, because the volume is a reflection of metabolic activity, it was expressed at standard pressure, standard temperature, and dry (STPD). A sample calculation is presented in the appendix.

The basal metabolism was expressed, for the purpose of analysis and interpretation under changing conditions, in terms of:

a) total Oxygen Consumption, in c.c. per minute.

b) oxygen Consumption per kg. of total body weight, in

c.c. per kg., and

c) oxygen Consumption per kg. of fat-free body weight, in c.c. per kg.

Static Strength Measurements. A Preston back and leg dynamometer was used for measuring the back and leg lifts, and a manuometer, of the rectangular type, was used for the determination of grip strengths. Both instruments were calibrated in pounds and the back and leg dynamometer was permanently mounted on an 18 inch bench to facilitate more efficient and accurate test administration. Three trials were provided at each testing session and the highest poundage recorded as the subject's "maximum" volitional strength for the particular test under study.

1. Grip, Back Lift and Leg Lift. The administration of the four tests was carried out according to the procedure as outlined by Clarke (8:188) (see Appendix C).

The testing technique for the leg lift (with belt) differed slightly from the suggested procedure in that the measured angle of knee flexion remained constant, 110 to 115 degrees, for each trial.

2. Total Proportional Strength. (T.P.S.). The summation of the "maximum" strengths recorded for each of the four tests was considered as the "total proportional strength."

3. Strength per pound of body weight and fat-free body weight. These ratios were determined by dividing the "total proportional strength" by the total body weight and the fat-free body weight, respectively, of the individual.

Balke Treadmill Test of Functional Potential. The treadmill performance test was used to assess the ability of the individual's circulo-respiratory systems, in terms of heart rate response, to adapt to increasing work loads.

On three consecutive days, immediately prior to the test, subjects were given trials of 3 to 5 minutes duration whereby they practised walking on the treadmill at a speed of 3.3 m.p.h. with varying gradients.

The test was administered according to instructions as outlined by Balke (8:74).

1. Each subject, dressed suitably for activity, stood on the treadmill and his pre-test heart rate was recorded for three minutes.

2. The subject then walked on the treadmill at a constand speed of 3.3 m.p.h., the grade being raised one per cent from the horizontal each minute. Heart rate was measured at the end of each minute from a continuously recording Sanborn electro-cardiograph until the heart rate reached 170 beats per minute, after which time the readings were taken every thirty seconds.

3. The subject continued exercising at increasing work loads until his heart rate reached 180 beats per minute.

4. The procedure was then terminated and the heart rate similarly recorded during a three minute recovery period. The subject's "work capacity" score was computed in terms of:

a) performance time, in minutes, and

b) total kg. metres of (mechanical) work completed.

The latter score was determined from the table devised by Pestalka (9) based on the speed of the treadmill (3.3 m.p.h. or 88.5 met./min.), the vertical height of the treadmill at test completion and the total mass of the individual in kgs.

The consistency of treadmill speed, at varying grades, was tested periodically and the paper speed of the electrocardiogram, which varied between 23 and 25 mm. per second, was checked preceding each test.

Questionnaires and Inventories

The forms used for the collection of data pertaining to both personal and evaluative information are presented in the Appendix.

1. Health and Fitness Questionnaire. This form was completed by all individuals (14) who were interviewed prior to the beginning of the study. The questionnaire, as well as the accompanying interview, was designed:

a) to discover any diseases or chronic ailments previously possessed by the individual,

b) to determine the activity participation and (generally) the dietary habits of the individual,

c) to discover the subject's opinions as to the cause of his "weight problem" as well as any problems of "overweight" which existed in his immediate family, and

d) to measure and record skinfold fat measurements which provided a subsequent classification for each subject.

2. Caloric Intake Inventories. Each subject tabulated the quantities of various foods eaten daily throughout the entire experimental period as well as over a period of three

weeks prior to experimental phase 1. The caloric equivalents of food portions were calculated from the "Canadian Dietary Standards and Food Values", 1950 (10).

3. Physical Activity Inventories. A daily record of physical activity was recorded by each subject during the Non-Instructional, phase 11, of the study. "Vigorous activity" was considered as those sports and exercises which were identical or comparable to the activities in which the subject participated during Instructional phases 1 and 111. The number of hours spent weekly in vigorous muscular activity was computed, totalled and compared to participation during the other phases of the study.

4. Program Evaluation Questionnaires. The aim of these questionnaires was to discover the subjects' personal reactions - likes and dislikes, to the exercise program. The forms were completed every two weeks throughout phases 1 and 111.

Activity Program Description. The activity program, as conducted during phases 1 and 111 of the study, may be described briefly according to its three basic components - exercise, sports and education. Each activity session lasted 50 to 60 minutes with the content of each session varying considerably from day to day.

a) Exercise. The aim of this aspect of the program was to introduce the subjects to the various forms of training, which included: interval training, progressive loading exercises, isometric contractions, running (track and cross country), circuit training, and "free" exercises which stresses high

repetitions with the body weight providing the resistance. The progression of exercises, that is the increase in intensity, was individually oriented and daily records were kept for each subject. During the initial phase of the study, the subjects were continually under close instruction and supervision. In phase lll, however, the subjects were allowed to choose their own type of training program.

b) Sports. Vigorous sports participation was included in almost every training session. The sports included: handball, squash and swimming. The stress was placed on vigorous, "continuous movement" participation and this pattern was maintained in both instructional and competitive situations.

c) Education. An attempt was made to "educate" the subjects in terms of providing general information concerning: i) the known physiological and anatomical implications of exercise and sport, and ii) the underlying principles, advantages, and disadvantages of the various types of physical training.

This information was made available through brief, periodic lectures, mimeographed materials, and informally, by encouraging and answering pertinent questions posed by the subjects.

Photographs

The subjects were photographed in the frontal, dorsal and profile positions. The subject stood at attention with the chest, abdomen and arms in a relaxed position. The photographs were taken immediately prior to phase 1 and at the termination of phases 1 and lll.

A Hasselblad 55 c. camera with an 80 mm. lens and triex film (speed rating of 400 A.S.A.) were used, with available lighting, for all photographs.

Correlation Study

The subjects consisted of 34 healthy college freshmen ages 17 - 28 years. The subjects were "relatively sedentary" in that for at least six months prior to testing, they had participated in no regular vigorous activity outside of their twice weekly physical education periods. All subjects had passed general medical examinations prior to university entrance.

The Balke treadmill test, as previously outlined, was administered to all subjects and measurements of standing pre-test heart rate, treadmill performance time, and recovery heart rate (5 minutes) were recorded. A detailed account of all physical activity participation over the preceding two years was obtained for each subject.

The following body measurements were also taken according to the procedures as previously described:

1. Standing Height (inches)
2. Total Body Weight (pounds)
3. Relative Body Weight (per cent)
4. Skinfold Fat (Chest, Tricep, Sub-Scapular, Supra-Iliac, Abdominal, and Front Thigh), in total mm.
5. Per Cent Body Fat and Fat-Free Body Weight (predicted from 4).

Relative body weight was determined in terms of a percentage of the standard or average weight (for height, age

and sex), by comparison with the abundant material compiled in the 1955 investigation of a Canadian population (11:867). By definition, 100 per cent relative body weight means normal weight, 110 per cent means 10 per cent overweight, etc.

The prediction of per cent body fat from the sum of six skinfold measurements was based on the equation as determined by Yuhasz (1:68):

% Body Fat = 0.097 (total fat in mm.) +3.641. Standard Error of Estimate = 2.878.

Statistical Treatment of Results

Longitudinal Study. The changes observed in all measurements from test to test were presented graphically for each of the seven subjects in order to provide an easily discernible analysis of weight changes in terms of the other variables. Changes in total weight and weeks of activity participation were plotted against:

a) daily caloric consumption
b) fat and fat-free body weights
c) subcutaneous fat changes
d) gross and fat-corrected body dimensions
e) basal oxygen consumption
f) treadmill performance time
g) total proportional strength

The subjects were considered collectively for an evaluation of initial and final test results in comparison with previous findings.

Mean values for six of the seven subjects (excluding

M.B.) were determined for all measurements at each of the four testing periods. A test for paired samples (12:186) was applied to determine if the differences between mean scores were significantly different from zero at the .05 and .01 levels of confidence.

Correlation Study. An inter-correlation matrix for all variables was built with the use of the I.B.M. - 1620 Electronic Computer. This program (No. 6.0047) also provided a mean and standard deviation for each variable.

A first order partial correlation coefficient (13) between per cent body fat and treadmill performance time was computed, with the effect of total body weight partialled out. At test with n - 3 degrees of freedom was used to determine if the partial r was significantly different from zero at the .01 level of confidence.

The inter-correlation matrix was then used as a basis for the computation of a multiple regression equation between treadmill performance time as the dependent variable and five measurements of body mass and body composition. The equation was calculated by means of the "Stepwise Procedure for Multiple Regression" (14), a program designed specifically for electronic digital computers. This procedure requires that at each successive stage or "step" in the formation of the equation, that variable is added which accounts for the largest proportion of the remaining variation in the dependent variable. In other words (15:192): "The variable added is that one which makes the greatest improvement in the "goodness of fit"." The t ratio for

N-n-1 degrees of freedom provides a test to determine if the beta coefficient computed for each variable is significantly different from zero (.05 and .01 levels of confidence). Standard errors of estimate, of predicted from actual values, are also determined for each successive regression equation.

The relationships found, between body measurements and treadmill performance time with sedentary males, were also examined with the seven individuals who had completed a program of vigorous training. This analysis was carried out in the following manner:

a) General observations were made from graphical illustrations depicting changes in both treadmill performance and body measurements.

b) The regression equations computed for the sedentary group were used to predict the treadmill times of the seven "longitudinal" subjects from body measurements taken at Tests 1, 2 and 4. The errors found between predicted and actual times provided the basis for a comparative evaluation of the treadmill performance - body measurements relationship under both sedentary and "trained" conditons.

A sub-sample of twenty subjects was completely tested and re-tested on consecutive days and Pearson - product moment reliability coefficients of correlation determined for each measurement.

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CHAPTER IV

RESULTS AND DISCUSSION

Reliability Coefficients

The Pearson product-moment coefficients of correlation for consecutive day test-retest conditions are presented in Table IX for all measurements.

Reliability measurements were not carried out with the same subjects on all of the measures necessary for the determination of body density. Correlation coefficients are thus reported only for each of the component measures - apparent weight in water at maximal inspiration, and total lung capacity. These measures were tested (on consecutive days) with different samples, the number in the latter measurement totalling only eleven. A reliability coefficient of .964 with lung capacity determinations resulted in a mean difference of 124 cc. between the two trials. This difference would account for a measurement error of .0017 density units on the average and thus result in an error of .7% in the estimation of per cent body fat from the formulae of Brozek and Keys (1:268). The values for partially submerged vital capacity were discarded due to the inconsistency and questionable accuracy of the portable vitalometer used for this purpose. Submerged body weights taken after the subject had expired maximally were also not used. The majority of the subjects were either non or beginning swimmers and their apprehension over such a test resulted in an inability to relax as well as to exert a truly maximal expiration prior to submersion. All experimental subjects underwent a minimum of 15 submersion trials

TABLE IX

Consecutive Day Test-Retest Reliability

Coefficients (N = 20)

Measurement		
A. Total Weight and Skinfold Fat		
Total Body Weight (lbs.)		r = .999
Skinfold Fat Measurements		
Bicep	(mm.)	r = .993
Tricep	(mm.)	r = .996
Chest	(mm.)	r = .964
Sub-Scapular	(mm.)	r = .983
Supra-Iliac	(mm.)	r = .993
Umbilical	(mm.)	r = .997
Front Thigh	(mm.)	r = .991
Rear Thigh	(mm.)	r = .983
Total Fat	(mm.)	r = .991
B. Body Dimensions		
Gross Upper Arm Girth	(ins.)	r = .993
Fat-Corrected Upper Arm Girth	(ins.)	r = .991
Gross Thigh Girth	(ins.)	r = .989
Fat-Corrected Thigh Girth	(ins.)	r = .951
Calf Girth	(ins.)	r = .977
Abdominal Circumference	(ins.)	r = .901
C. Body Density-Lung Volumes		
Apparent Weight in Water (lbs.) (maximal inspiration)		r = .983
Total Lung Capacity on land (N = 11)	(litres)	r = .964
D. Strength Measurements		
Right Grip	(lbs.)	r = .654
Left Grip	(lbs.)	r = .871
Back Lift	(lbs.)	r = .882
Leg Lift	(lbs.)	r = .847
Total Proportional Strength	(lbs.)	r = .840

Table 1X continued ...

Measurement		E. Treadmill Performance
Performance Time	(mins.)	r = .964
Pre-Test Standing Heart Rate	(beats /min.)	r = .419
Recovery Heart Rate - at 3 minutes	(beats /min.)	r = .063
Recovery Heart Rate - at 5 minutes	(beats /min.)	r = .345

prior to the initial set of tests at the beginning of Phase 1.

Much difficulty was found in obtaining a medial skinfold in the calf region due to the lack of fat deposition. The gross circumference of the calf was considered also then to be representative of the musculature in the area.

All reliability coefficients were substantially above the level required for significance at .01 level of confidence (r = .549) with the exception of the three heart rate measures taken prior to and in recovery from the treadmill test. These non-significant measures were not considered in the presentation or discussion of results.

Initial Evaluation of Subjects

The results of the initial testing session (beginning of Phase 1) are compared in Table X to the findings of other authors who have studied "untrained" college men in the 18 to 30 years age range (2, 3, 4, 5, 6, 7). This comparison includes results from a previous study by the present author (2) in which similar measures were performed with identical techniques. In studies where the pertinent results were not reported, calcu-

Table X

Initial Values of Selected Measures for Each Subject
(N = 7)

Selected Measures	R.H.	C.B.	M.G.	G.H.	L.Y.	J.D.	M.B.	-Mean- College Men
Total Body Wt. (lbs.)	264.25	266.25	207.25	183.0	170.0	160.0	126.50	174.68 a 168.40 b
Relative Body Wt. (%)	179	163	138	105	109	101	72	100 c
% Body Fat (%)	35.0	33.9	21.8	20.0	13.2	7.9	3.1	9.89 a 10.68 b
Fat-Free Wt. (lbs.)	171.76	175.99	162.07	146.40	147.56	147.36	122.58	155.19 a 150.20 b
Total Proportional Strength (lbs.)	534	627	957	754	962	919	789	1097 d
Str./lb. wt.	2.02	2.37	4.62	4.13	5.66	5.74	6.23	6.74 d
Treadmill Performance Time (mins.)	7.0	5.5	11.0	15.0	15.5	17.0	16.0	15.8 e
Basal O_2 Intake: Per kg. wt. (c.c./kg.)	2.71	2.73	3.09	3.25	3.75	3.58	4.22	3.41 a 3.91 f
Basal O_2 Intake: Per kg. fat-free wt. (c.c./kg.)	4.17	4.14	3.95	4.07	4.32	3.89	4.35	3.89 a 4.17 f
Basal O_2 Intake: %age of "Standard" B.M.R. (%)	95	96	91	95	112	100	100	102 a

a Dempsey (1963) N = 50 b Yuhasz (1962) N = 116 c Pett (1955) d Yuhasz (1961)

e Correlation Study N = 34 f Von Dobeln (1956) N = 35

lations were made from the available data.

The very general pre-experimental classification into "obesity" groupings, based on three skinfold fat measures, was verified by the body density measures in 6 of the 7 cases. In order that ambiguity in classification may be prevented in further analysis of the data, each subject was identified in all subsequent graphs and tables according to the initial (Test 1) percentage of his weight which was composed of fat.

All of the subjects, except M.B., were "overweight", from 1 to 79 per cent of their particular height, age and sex. The differences among subjects in per cent of body fat or "relative obesity", however, did not exactly correspond with the differences in relative body weight.

The fat-free body weights of the three most obese subjects were heavier by 16 to 29 pounds over subjects G.H., L.Y. and J.D. These latter three subjects ranged in total body weight from 160 to 183 pounds with a 1.16 pound difference in the weight of their bodies devoid of fat.

Muscular strength, per pound of body weight ratios, was found to be lowest with the most obese and increased steadily up to the leanest subject, M.B. All subjects were considerably lower, in both T.P.S. and the strength-weight ratio, than the means reported for college men.

All subjects, excluding J.D., were either quite comparable to or well below the mean treadmill performance time found with the sedentary group in the correlation study. The lowest time presently found in the 34 sedentary subjects and

also reported by Hodgson (8) was 11 minutes, occurring in one case in each of these two samples. The two very obese subjects were well below this time and subject M.G. equalled it.

Basal oxygen consumption expressed as cc. per kg. of weight showed a steady decline from 4.22 to 2.71 as obesity increased from subject to subject. When the weight of the fat-free body mass was employed as a reference standard, the B.M.R.s of the various subjects remained relatively constant.

The means and standard deviations for the relatively sedentary sample of 34 used in the correlation study were compared to the findings of Yuhasz (3) and Hodgson (8) from measurements carried out on "normal college males" (Table XI). Yuhasz (3) also used the Harpendon Skinfold Caliper for his measurements of subcutaneous tissue.

The sedentary sample walked 1.5 minutes longer on the treadmill than did the group studied by Hodgson. The latter sample had higher average standing heart rates - pre-test and at three minutes of recovery than was shown by the present group.

Anthropometrical Analysis of Weight Change

The training and testing procedures are outlined below. In subsequent graphs and tables, Test 1 (T1) refers to the beginning of phase 1, Test 2 (T2) to the termination of phase 1... etc.

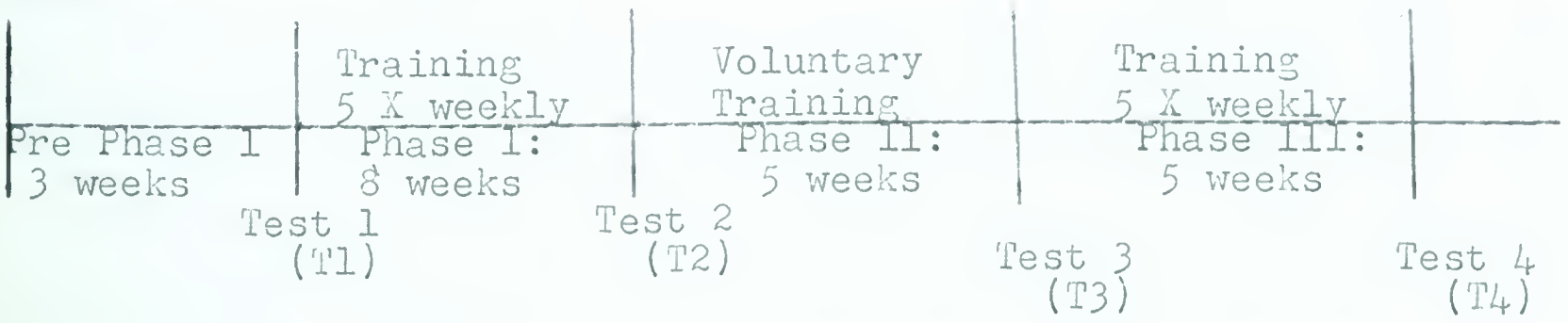


TABLE XI

Means and Standard Deviations For Sedentary Sample (N - 34)

Measurement		Sedentary Sample Mean	S.D.	College Men -Related Studies- Mean	S.D.	
Height	(ins.)	70.1	2.41	___	___	
Weight	(lbs.)	164.98	21.89	156.67	19.23	a
				168.40	19.75	b
Relative Wt.	(%)	107.0	19.3	106.0	___	
Total Skinfold Fat	(mm)	98.3	45.5	72.6	44.17	b
% Body Fat	(%)	12.93	5.90	10.68	4.28	b
Fat-Free Body Weight	(lbs.)	142.13	16.30	150.19	15.77	b
Standing Pre-Test Heart Rate	(beats /min.)	78.4	13.4	88.0	___	a
Treadmill Performance Time	(mins.)	15.8	3.69	14.3	2.40	a
Recovery Heart Rate - 3 mins.	(beats /min.)	114.8	8.50	117.0	___	a
Recovery Heart Rate - 5 mins.	(beats /min.)	110.0	9.20	108.0	___	a
Age	(yrs.)	19.8	1.71	18.6	___	a
				21.5	2.01	b

a Hodgson (1963) (N = 33)

b Yuhasz (1962) (N = 110)

During phase 11 none of the subjects continued to maintain the daily program of activity followed during phase 1. The activity recall forms pointed out that:

a) Subjects J.D., C.B. and M.B. participated in no formal exercise or sports.

b) Subjects L.Y. and R.H. maintained a daily program of walking and/or jogging throughout the five weeks.

c) Subjects M.G. and G.H. swam and skied two to three times weekly. G.H. assumed regular daily training during the last two weeks of this period.

d) None of the subjects continued with any type of progressive resistance exercise in terms of strength or endurance training.

Weight Pattern Change - Daily Caloric Consumption.

Reported daily caloric consumptions were averaged for each phase as well as the three weeks constituting "Pre-Phase 1" and are presented in Table X11. The differences between the mean caloric intake for pre-phase 1 and each of the three other phases did not reach the .05 level of significance. The highest t score of .542 was found in the increase between Pre-Phase 1 and Phase 111, 278 cals/day. A t value of 2.447 was required for significance at the .05 level of confidence with six degrees of freedom.

Individual patterns of weight change were plotted against daily caloric intake and weeks of activity participation and are presented in Figure 1V. In all three obese subjects daily caloric intakes rose during the first eight weeks of

TABLE X11

Average Daily Caloric Consumption
- Comparison of Mean Results For Each Phase -

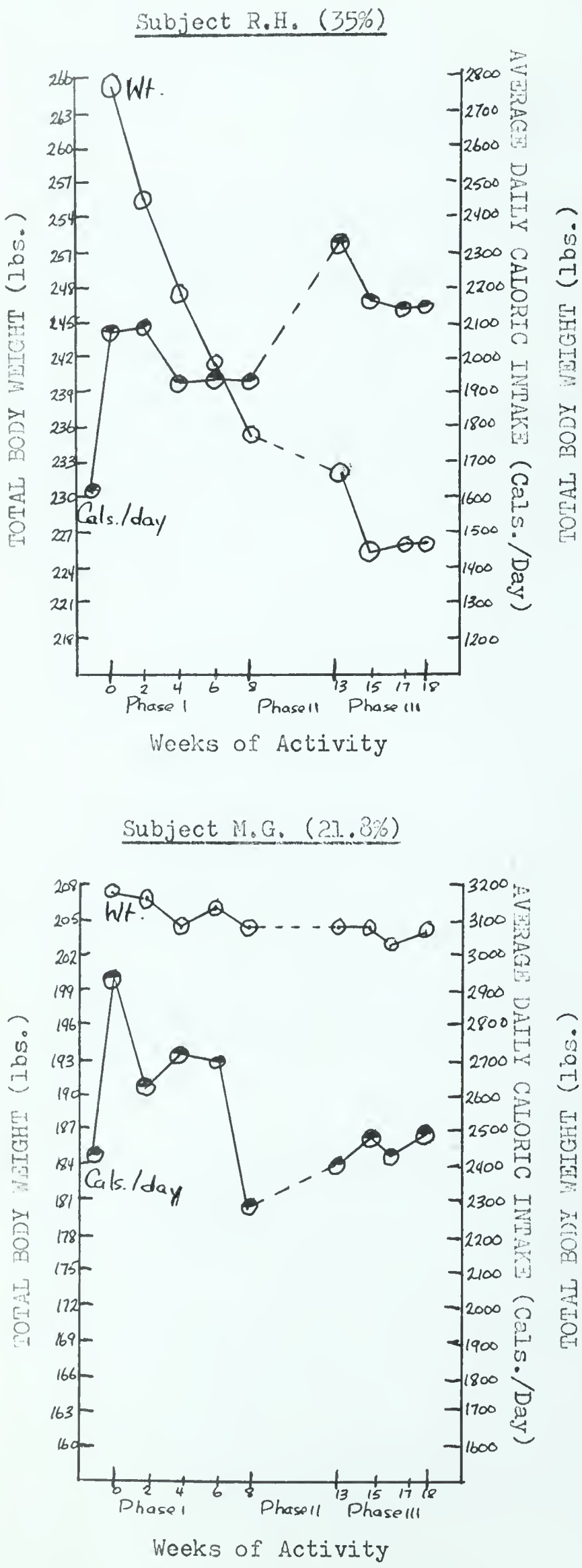
	- 3 wks. - Pre-Phase 1	- 8 wks. - Phase 1	- 5 wks. - Phase 11	- 5 wks. - Phase 111
Mean (cals/day	2003	2148	2190	2281
S.D.	276	323	265	237

training and stayed above the pre-experimental consumption for this period. During phase 11 all subjects showed a slight rise in daily caloric consumption over the final two weeks of training in phase 1, with the exception of subject C.B. who decreased from 2760 to 2700 calories per day. These fluctuations in daily caloric consumption throughout the first two phases were considerably reduced during the five weeks of phase 111.

Those subjects who reduced their total body weight (N = 6) lost the greatest percentage of their initial values during the first phase. This general observation in all subjects coincided with the mean and percentage losses for this particular group, which are shown in Table X111.

The pattern of weight loss for the group during phase 1 was one of general decline. Subjects L.Y. and J.D. gained 4 and 2 pounds of weight respectively during the final three weeks of exercise. These increases were preceded in the first two weeks of phase 111 by losses of 4 pounds (L.Y.) and 1.5 pounds (J.D.). Subject M.B. followed a similar pattern of weight change during this final five weeks of the program.

Figure IV
Caloric Consumption - Physical Activity and
Pattern of Weight Change



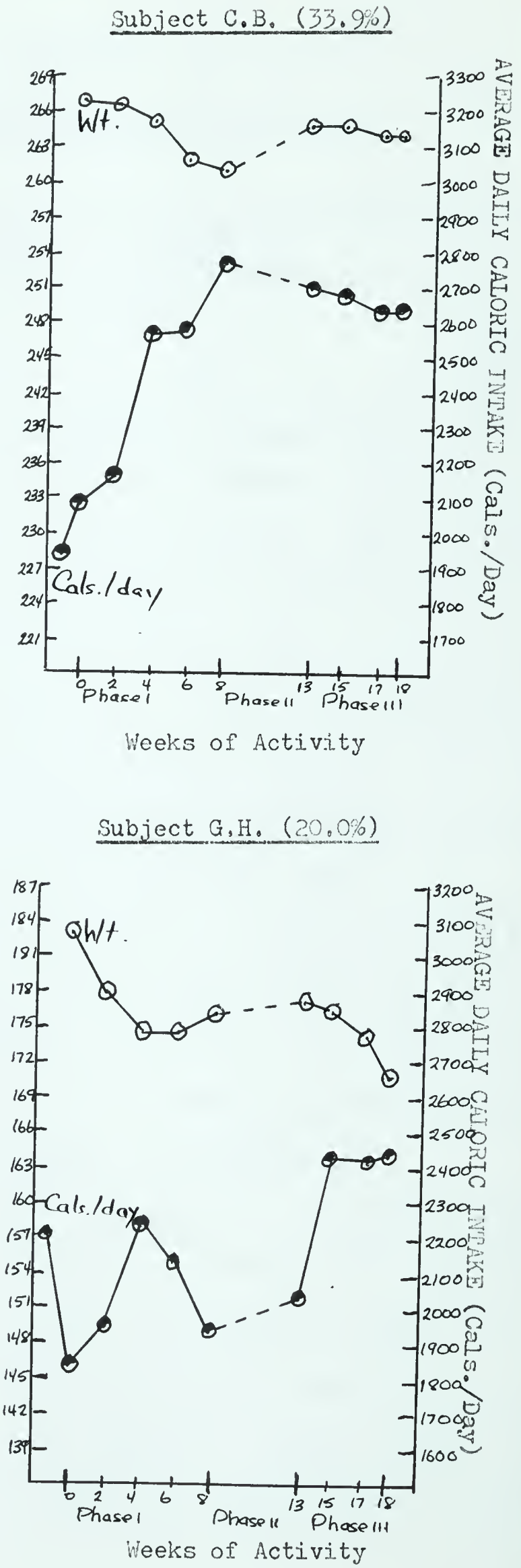
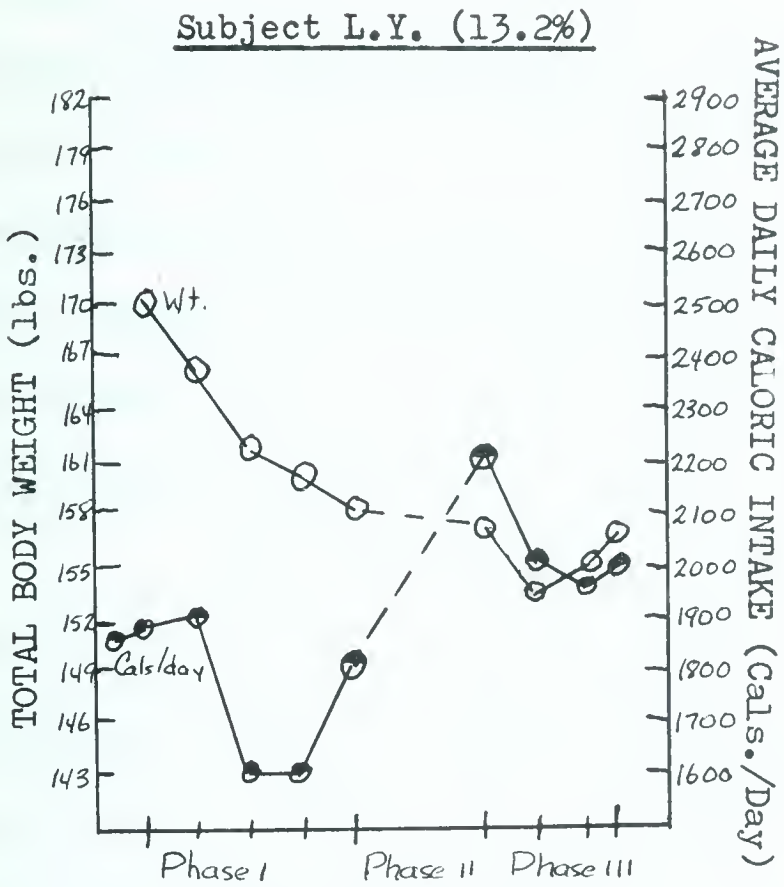
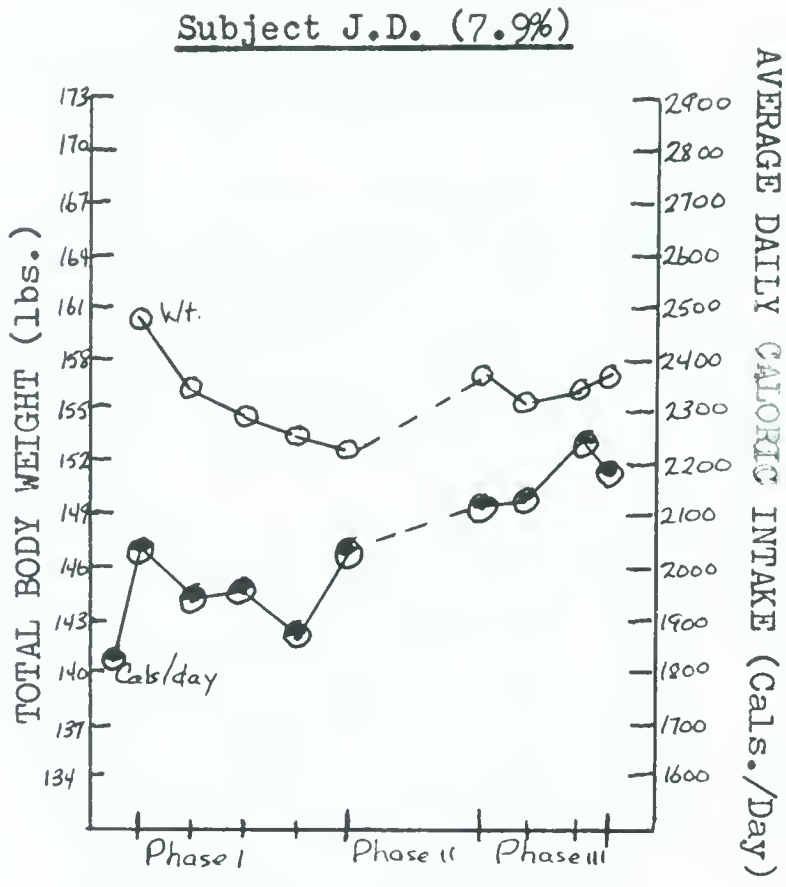
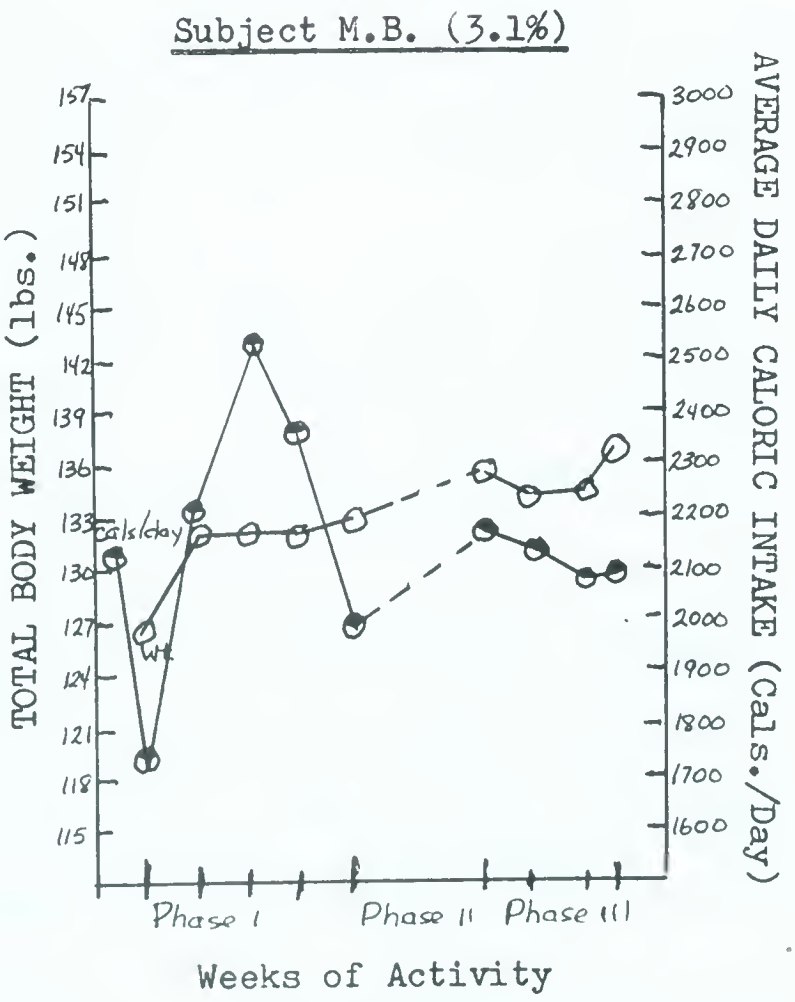


Figure IV (Con't.)









Means changes - Anthropometrical Data. The mean changes in body measurements are presented in Table XIII for six of the seven subjects. Subject M.B., initially, was 28 per cent "underweight" as well as having only three per cent of his weight composed of fat. These values diverged considerably from the initial results displayed by the other subjects and consequently the subject was excluded from any consideration of changes in the central tendency of the group.

The percentage changes of each measurement from the initial values are also shown. With total body weight, for example, 4.91 per cent of the initial mean weight was reduced at the end of phase I, 4.62 per cent over both phases I and II and 5.50 per cent over the entire 18 weeks.

The following observations may be drawn from the analysis of mean changes in anthropometrical measures:

a) Both total body weight and total body fat were reduced significantly (.05 level) during phase I and the 18 weeks of the program. The insignificant loss of weight (-2.01 lbs.) during phase III was less than one half of the fat loss (-4.21 lbs.) for this same period. A reduction of 5.50% from the initial mean value for weight was accompanied by a 42.66% loss in fat.

b) Along with a reduction in fat, weight loss was accompanied by significant mean increases in fat-free body weight and muscular mass* While muscle mass increased significantly over both the first and third phases, the gain in

*muscle mass was determined by fat-corrected upper arm and thigh circumferences plus gross circumference of calf.

weight of the fat-free body failed to reach significance during phase 1, the greater percentage of the total change in this component occurring in the final pahse. The percentage changes in both these measurements closely parallel one another throughout with the exception of phase 11 where muscle mass dropped .72 per cent and fat-free weight continued to rise .18% from the percentage changes of the initial values already established at the termination of phase 1.

c) A significant increase in muscular mass ($P \leq .05$) over phase 1 was accompanied by a significant reduction at the .01 level in the mean total gross circumference* This initial reduction, however, was followed by an increase in total gross circumference over the remaining two phases which produced an insignificant reduction of .42 inches for the entire 18 weeks. Abdominal circumference follows a similar pattern of change, in regard to significance as the above, but continues to decline (-.50 ins.) on the average during phase 111.

d) None of the anthropometrical changes observed during phase 11 (5 weeks) was significant ($P < .05$). A comparison of the mean percentage changes from the initial values, occurring at the termination of phases 1 and 11, also shows that the mean changes in all measurements occurring during phase 11 were not sufficient in magnitude to offset completely the changes attained during the first eight weeks of exercise.

*total gross circumference - sum of three gross circumferences at the thigh, calf and upper arm sites.

TABLE XIII

Mean Changes - Between Tests and as a Percentage of Initial Values - for Anthropometrical Data (N = 6)

Measurement	Mean Changes - Raw Score and % of Initial Values			
	T1 - T2	T2 - T3	T3 - T4	T1 - T4
Total Wt. (lbs.)	-10.55*	+ .25	- 2.01	-12.30*
% of initial	- 4.91%	- 4.62%	- 5.50%	-----
Relative Wt. (% of "standard")	- 6.5 **	+ .67	- 1.5	- 7.33**
Total Body Fat (lbs.)	-12.95*	- .69	- 4.21*	-17.04*
(% of initial)	-35.29%	-30.85%	-42.66%	-----
Per Cent Body Fat	- 4.5 **	- .1	- 2.0	- 6.6 **
% of initial	-32.39%	-27.94	-40.45	
Fat-Free Wt. (lbs.)	+ 2.40	+ .45	+ 2.37*	+ 5.24**
% of initial	+ 1.41%	+ 1.59%	+ 3.24%	-----
Skinfold Fat (mm.)	-61.13**	+ 4.8	-23.0 **	-79.86**
% of initial	-27.52%	-25.59%	-34.30%	-----
Total Gross Circumference (ins.)	- 1.43*	+ .22	+ .75	- .42
% of initial	- 2.29%	- 1.47%	- 2.01%	-----
Total Muscle Mass (ins.)	+ .40*	- .33	+ 1.3 **	+ 1.57**
% of initial	+ 1.21%	+ .49%	+ 3.36%	-----
Abdominal Girth (ins.)	- 2.50**	+ .45	- .50	- 1.00
% of initial	- 6.20%	- 5.02%	- 6.80%	-----

* sig. at .05 level; t ≥ 2.571
**sig. at .01 level; t ≥ 4.032 with 5 degrees of freedom

Densitometric Analysis of Individual Weight Changes. A graphical analysis of total weight change in terms of the fat and fat-free body components (derived from densitometric techniques and the formula derived by Brozek and Keys (1) is presented for each subject in Figure V. Weights are plotted in intervals of six pounds on the graphs for subjects R.H. and C.B., while the five remaining subjects have their weights plotted in intervals of 3 pounds.

This figure also includes an analysis of weight changes in terms of muscular mass as well as the fat and fat-free body components. The analysis is in the form of bar graphs with cumulative changes, after each phase of the study, shown as a percentage of the initial values for each measure.

During phase 1 subjects C.B. and M.G. differ somewhat, in the composition of their weight losses, from the remainder of the group. With subject C.B., a weight loss of five pounds was composed of a fat loss of 12.4 pounds and a gain in fat-free weight of 7.4 pounds. Subject M.G. reduced his initial weight by 3.25 pounds over the first eight weeks accompanied by changes in fat-free body and total fat weights of +2.15 pounds and -5.40 pounds respectively. Total weight did not change for this subject from Test 3 to Test 4. Total body fat and fat-free weights, however, each showed a reduction and gain, respectively, of 4.09 pounds.

These two subjects lost the least amount of weight of any of the subjects losing weight, in terms of both weight in pounds and as a percentage of their initial values. Over the

course of the entire program, per cent body fat was reduced from 33.0 to 29.6 per cent with C.B. and from 21.8 to 17.2 per cent with M.G.

Subject R.H. lost the most weight, a total of 38.25 pounds, throughout all phases of the study. This loss constituded 14.47% of his initial weight and was composed of a loss of 42.32 pounds of fat, a gain of 4.07 pounds of fat-free weight and a 2.25 per cent increase in muscle mass. Per cent body fat was reduced from 35.0 to 22.9 per cent from Test 1 to Test 4.

Subject G.H. lost a total of 12.0 pounds or 6.56 per cent of his initial weight over the 18 weeks, with the weight loss almost equally divided between phases 1 and 111. The weight change was composed almost entirely of a 12.69 lb. loss in fat, the weight of the fat-free body increasing only 1.69 pounds. This subject reduced his per cent body fat from 20.0 initially to 13.9 per cent at the termination of phase 111.

Subjects J.D. and L.Y. attained their greatest losses in total body weight at earlier stages of the study than the termination of Phase 111. J.D. lost 4.53 per cent or 7.25 pounds of his initial weight along with 0.74 pounds of fat by the end of the first eight weeks of training. After both fat and total weights had gained proportionately during phase 11, total weight remained steady at 157 pounds at the termination of phase 111. Both total fat and fat-free weights, however, showed a decrease and increase, respectively, of 4.06 pounds from Test 3 to Test 4.

Subject L.Y. changed his body composition and weight in a somewhat similar manner to J.D. His greatest fat (-14.96 pounds) and weight losses (-14.25 pounds), however, had occurred by the end of Phase 11. This loss was followed over the course of Phase 111 by a gain of 1.25 pounds and 3.02 pounds in gross and fat-free weight respectively, and a further loss of 1.77 pounds of fat.

During phase 11, the five weeks of voluntary activity:

a) Further loss of weight and fat occurred in subjects R.H. (-3.0 pounds) and L.Y. (-2.25 pounds).

b) Subjects J.D. and C.B. regained 4.25 pounds and 4.0 pounds of weight respectively.

c) Subjects M.G. and G.H. maintained the weight and fat losses observed at the termination of phase 1.

Anthropometrical changes with subject M.B. were in direct contrast to those experienced by the six initially overweight subjects. Throughout the full 18 weeks, body weight steadily increased a total of 8.3 per cent from the initial value which caused a change in relative body weight from 72 to 84 per cent of the standard. Over each phase of the experiment, the subject changed, anatomically, in the following proportions:

	Phase 1	Phase 11	Phase 111
weight (lbs.)	+5.75	+3.00	+1.75
fat-free weight (lbs.)	+5.67	+1.05	+2.36
fat weight (lbs.)	+ .08	+1.95	- .61

The total weight gain was 10.50 pounds which was composed of 13.5 per cent fat and 86.5 per cent fat-free tissue.

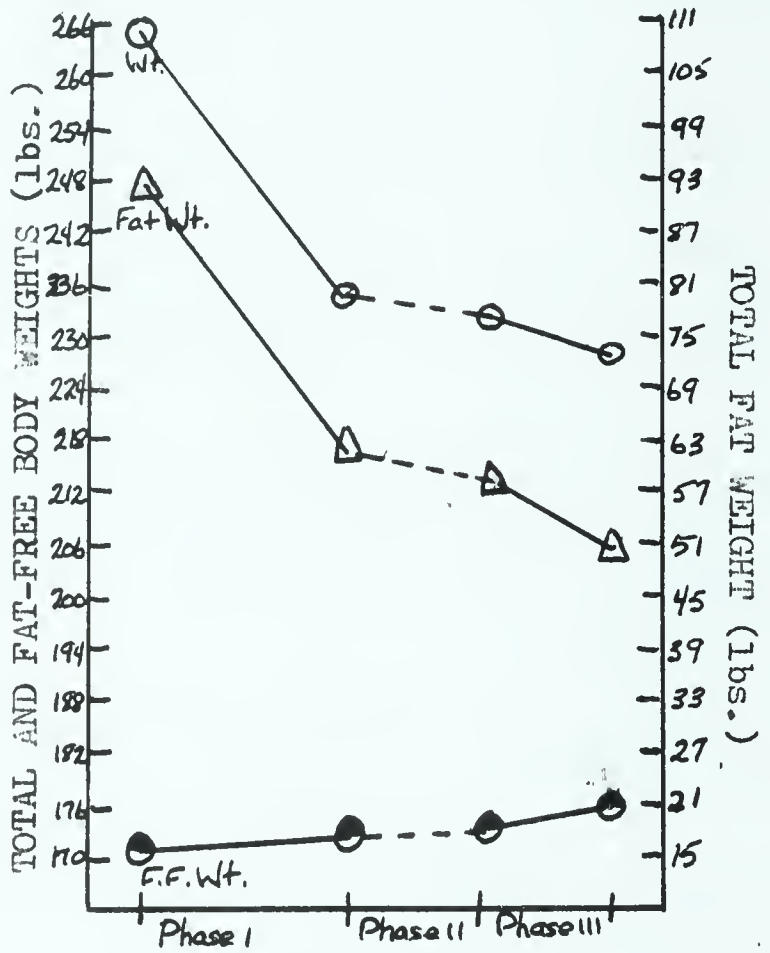
Figure V

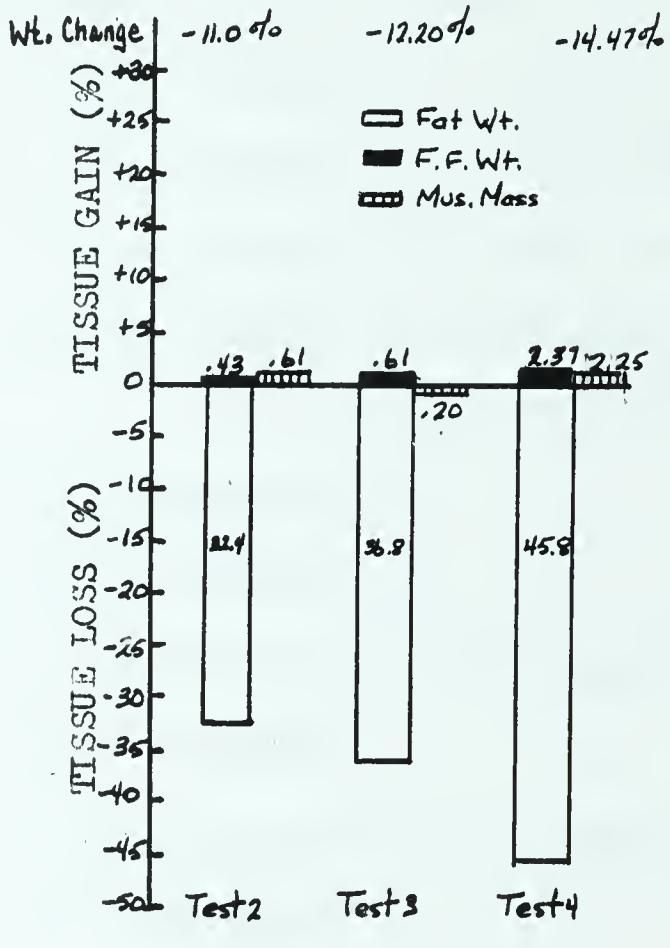
Densitometric Analysis of Total
Body Weight Changes

The Weights of the Total Body, Body Fat and the Fat-Free Body

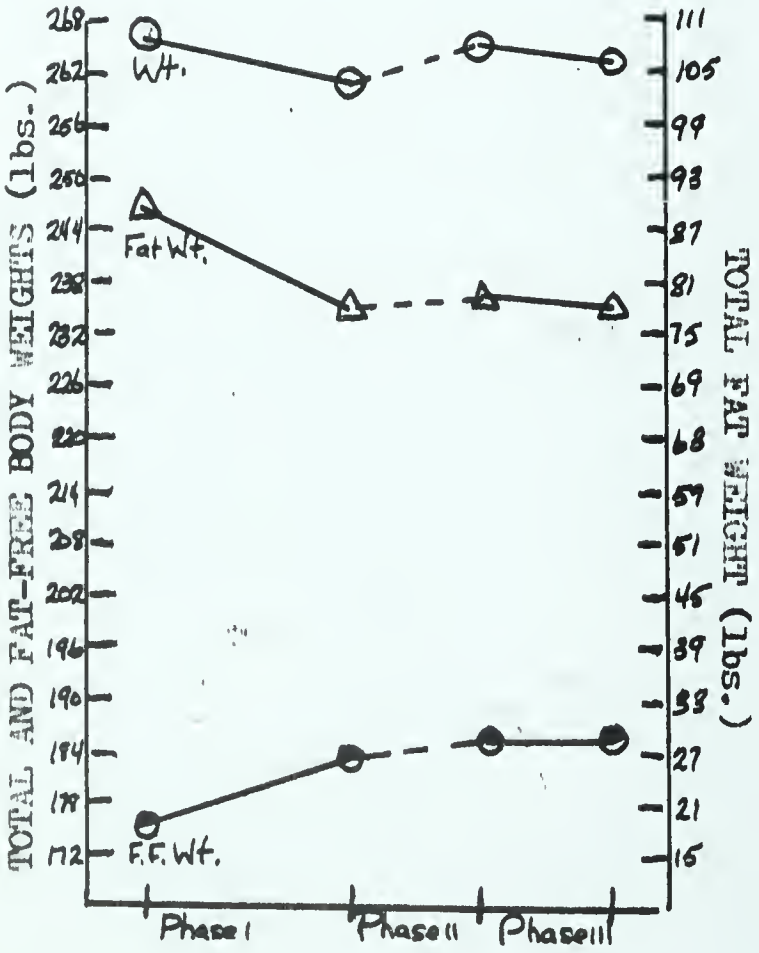
%age Changes in Body Tissues (% of Initial Values)

Subject R.H. (35.0%)





Subject C.B. (33.9%)



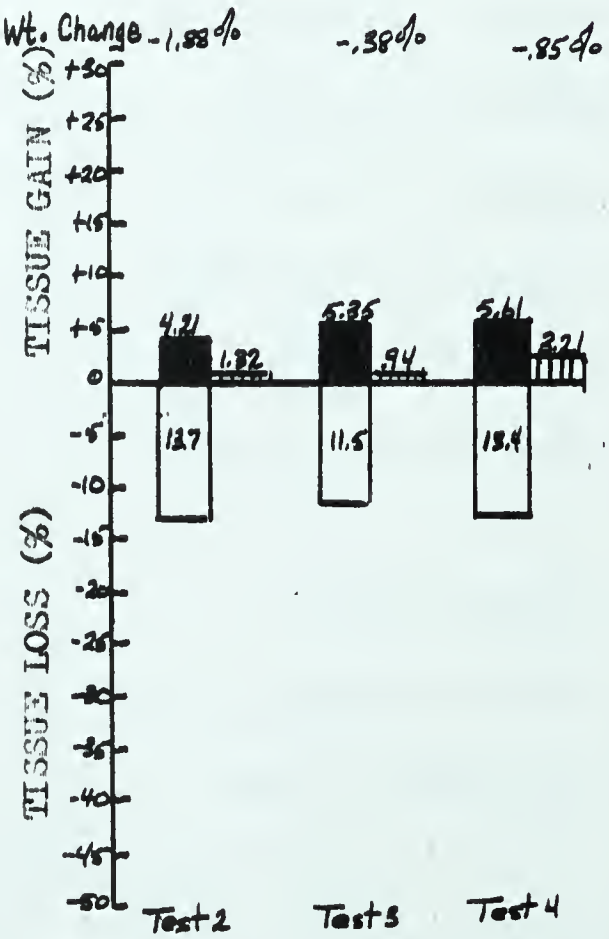
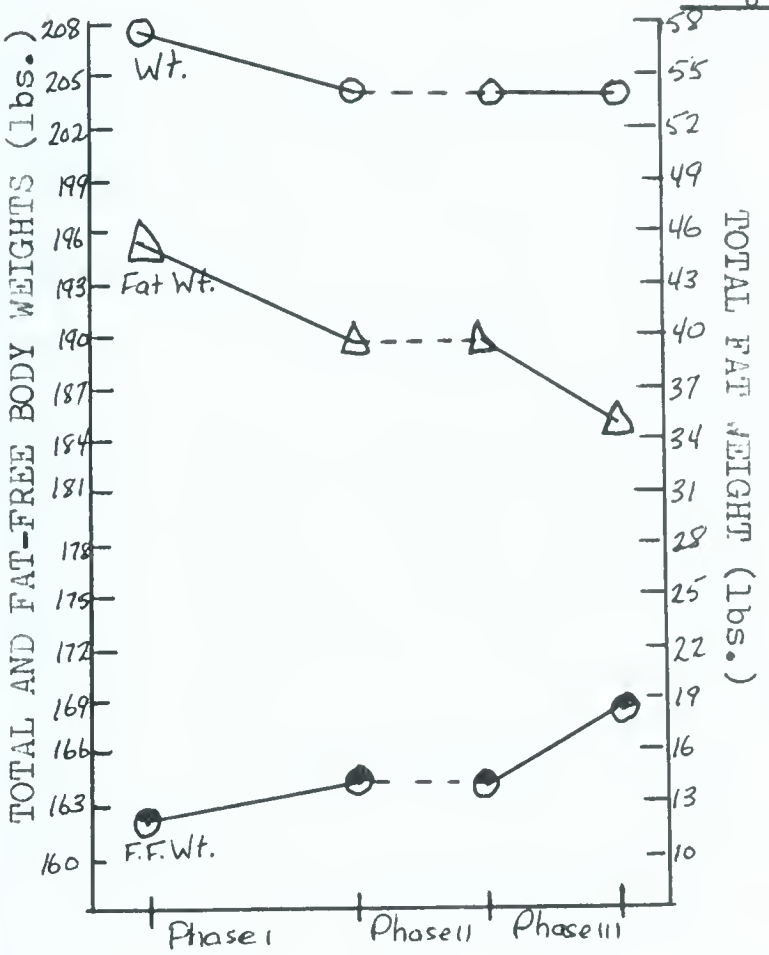


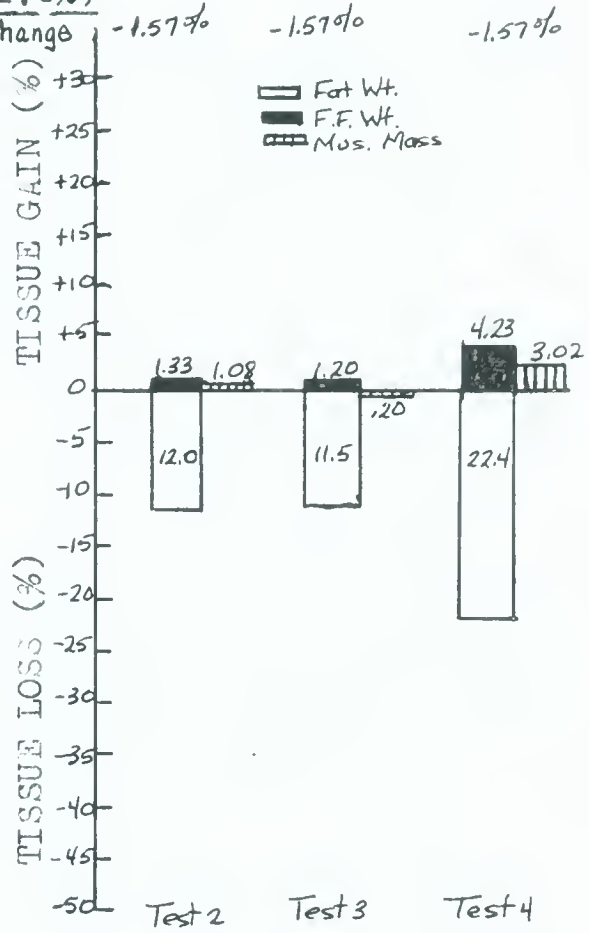
Figure V (Con't.)

The Weights of the Total Body, Body Fat and the Fat-Free Body

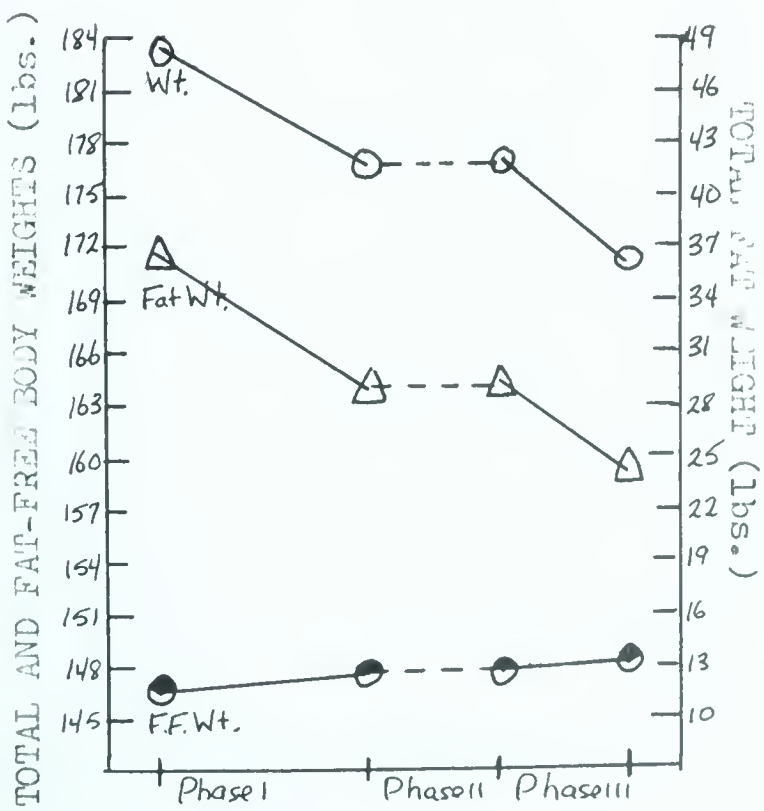
Subject M.G. (21.8%)



Percentage Changes in Body Tissues (% of Initial Values)



Subject G.H. (20.0%)



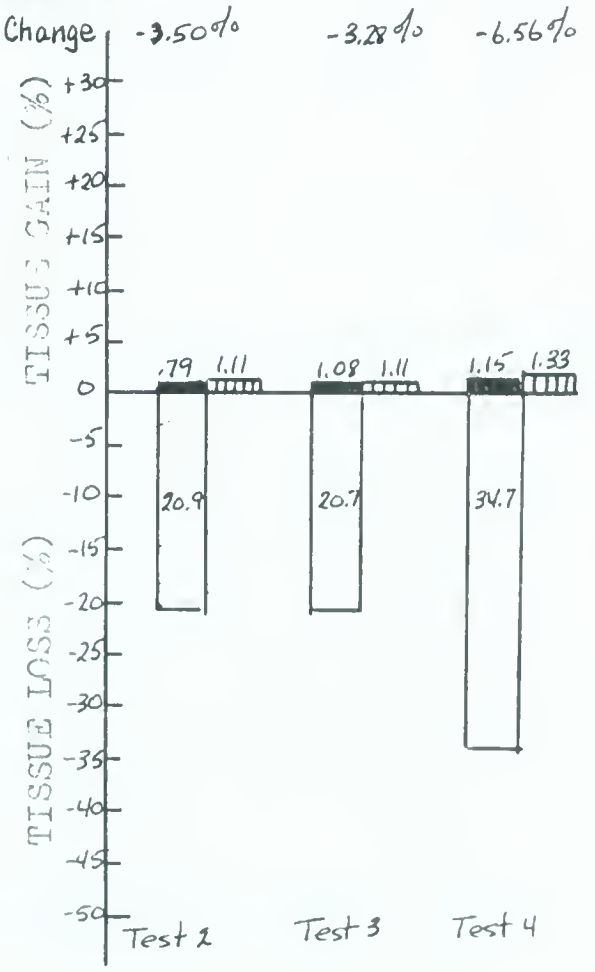
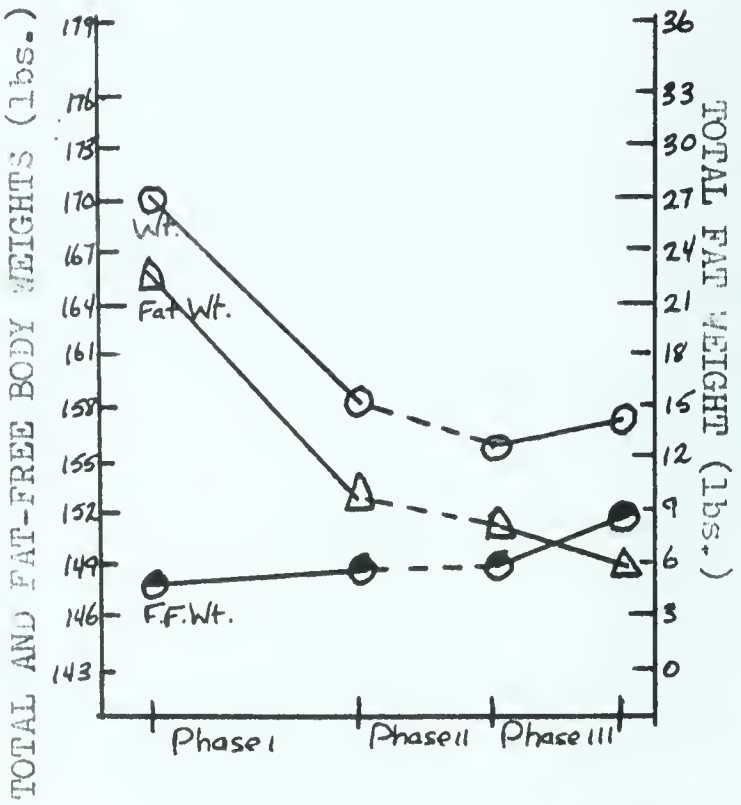


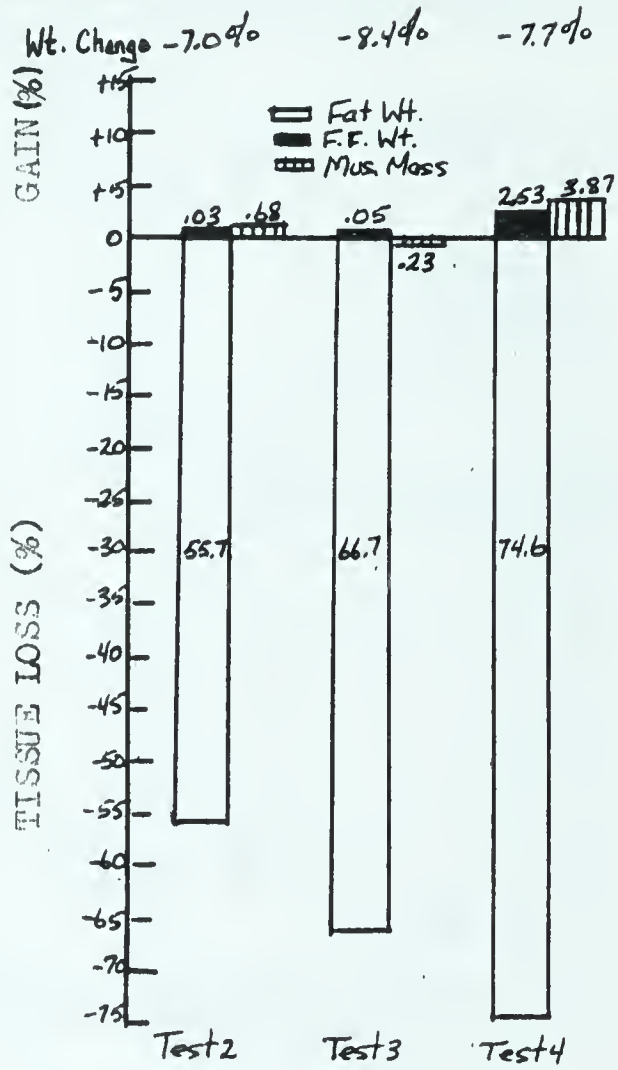
Figure V (Con't.)

The Weights of the Total Body, Body Fat and the Fat-Free Body

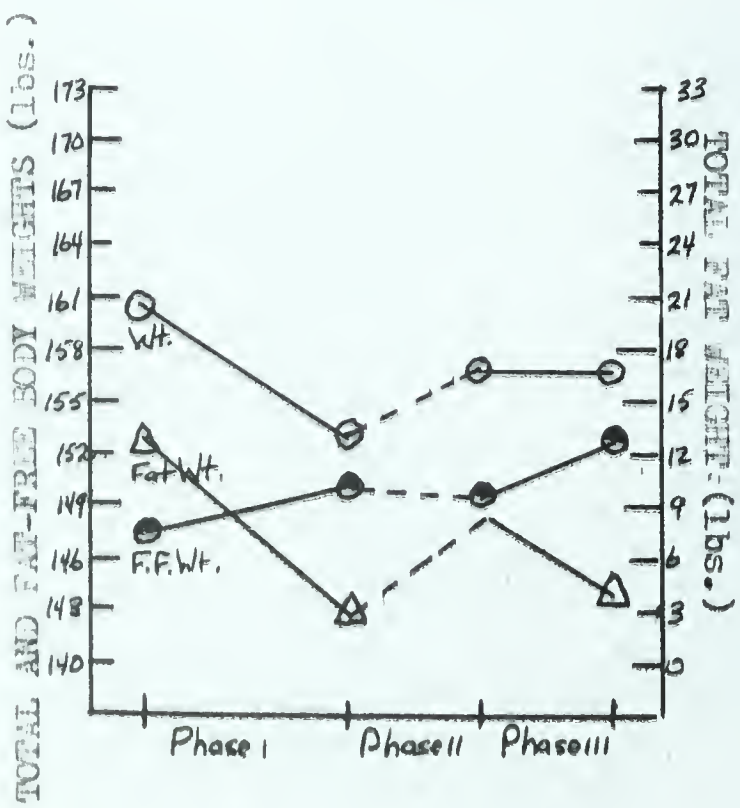
%age Changes in Body Tissues (% of Initial Values)

Subject L.Y. (13.2%)





Subject J.D. (7.9%)



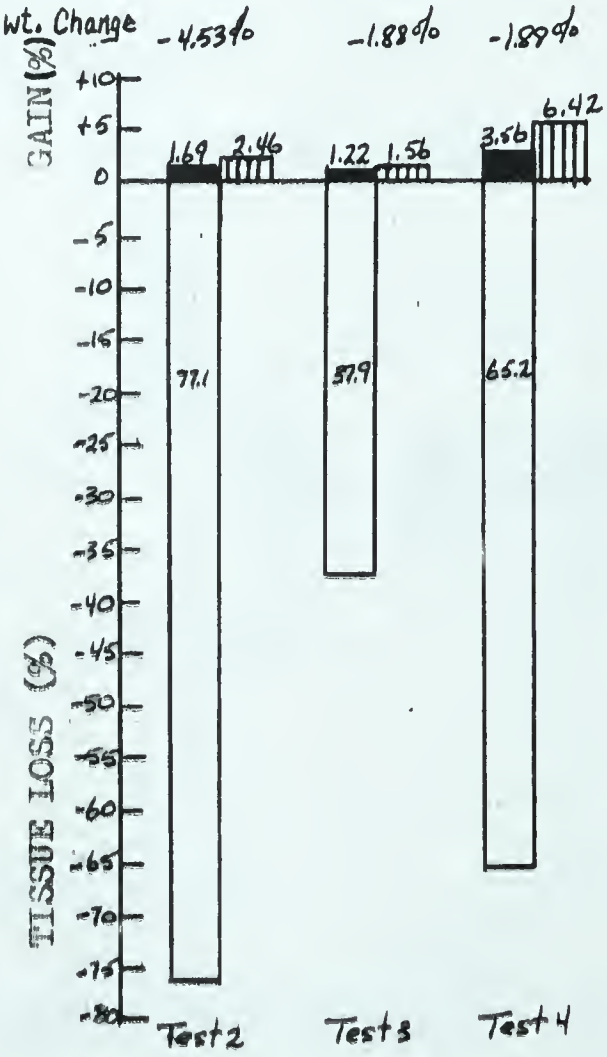
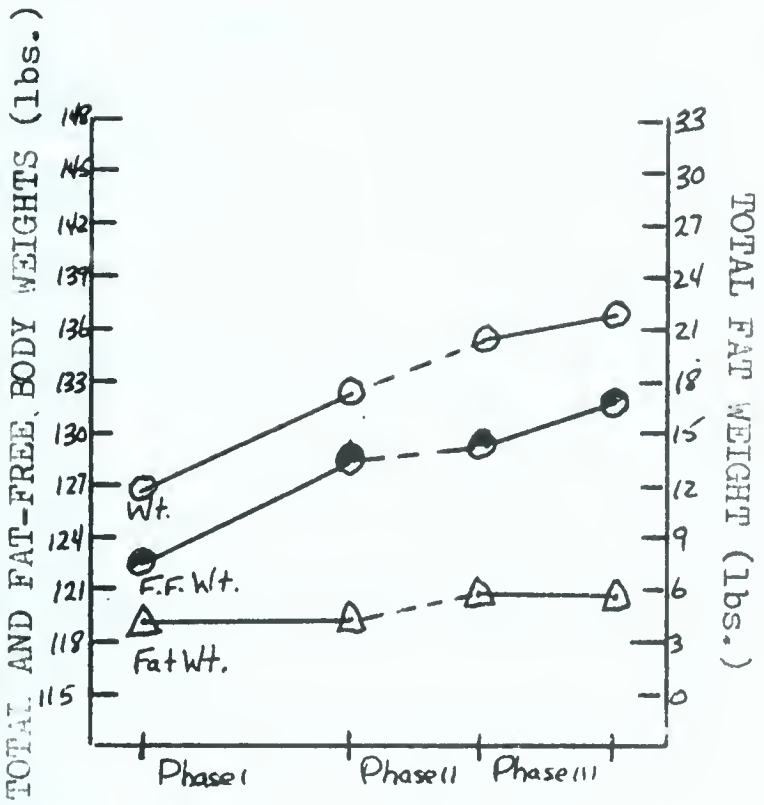


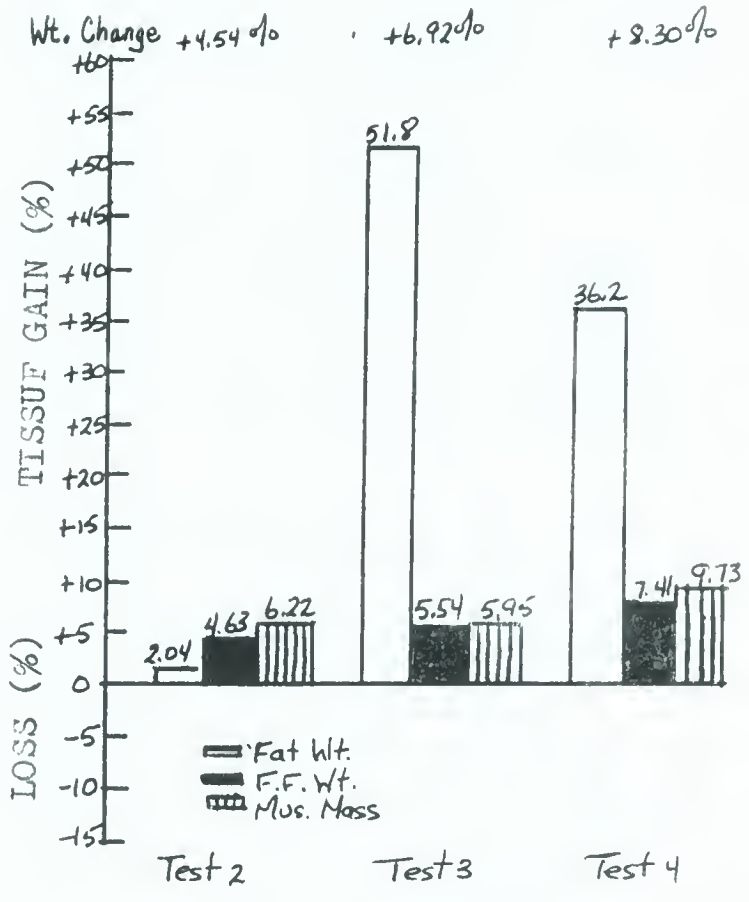
Figure V (Con't.)

The Weights of the Total Body, Body Fat and the Fat-Free Body

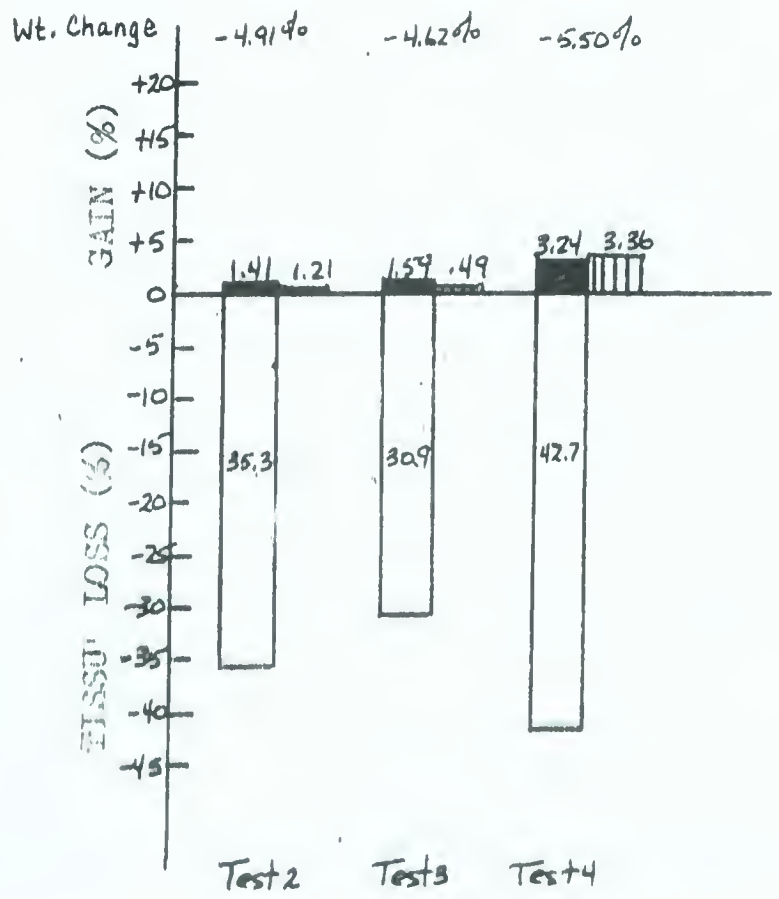
%age Changes in Body Tissues (% of Initial Values)

Subject H.B. (3.0%)





Mean % Changes in Body Tissues (N=6)
(% of Initial Values)



This subject also increased his original muscle mass a total of 9.73 per cent. The greatest gains in both fat-free and muscle mass occurred during the initial eight weeks of the program.

Changes in Body Dimensions. Changes in both gross and fat-corrected limb circumferences (three sites) are plotted against total and fat-free body weight changes in Figure V1. An analysis of changes at each measurement site, including abdominal girth, accompanies each graph.

Five of the six originally overweight subjects (excluding J.D.) generally adhere to the mean changes which showed a significant decrease in total gross circumference coinciding with a significant increase in muscle mass, over the first eight weeks of exercise. During Phase 111, however, the total gross circumference remained at Test 3 values, while muscle mass continued to increase with both subjects R.H. and C.B. Subject C.B. lost only .5 pounds of fat during this period. R.H. continued to decrease his gross circumference at both the thigh (-.2 ins.) and upper arm (-.2 ins.) areas during this final five weeks, but gained .5 inches in the calf measurement, which was also serving as an estimation of the musculature at this site.

Subject L.Y. reversed his pattern of a decline (-2.5 ins.) in total gross circumference observed over the first two phases by increasing these measures a total of .4 inches during the final five weeks. This gross increase was accompanied by a gain of 1.8 inches in muscle mass.

Subjects J.D. and M.B. increased in both gross circumference and muscular mass measures throughout both phases

1 and 111. The total gain in muscle mass exceeded the gross circumference gain in J.D. by .4 inches, and these findings were exactly the reverse with subject M.B. J.D. showed a final loss in limb skinfold fat of 24.3 mm. (4 sites) while M.B. increased these measures by a total of 10.9 mm.

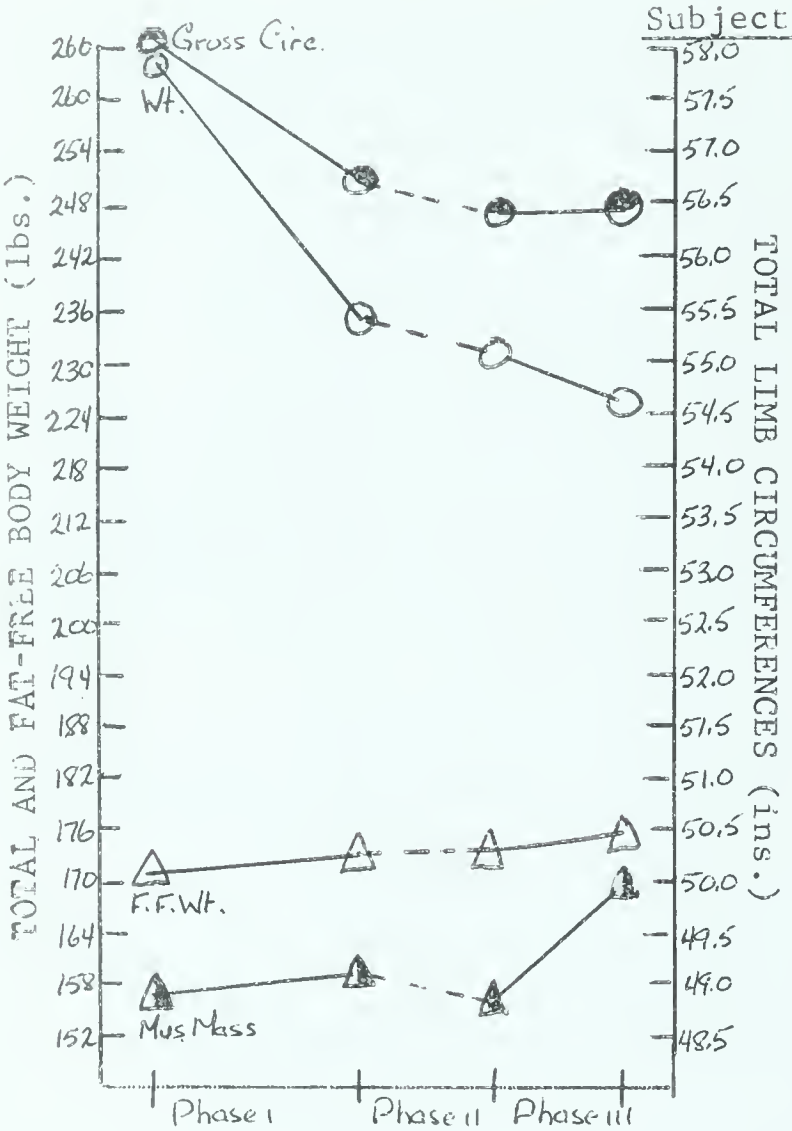
A difference of 2.3 inches was observed initially with J.D. and L.Y. between the total gross and fat-corrected measures, as compared to differences ranging from 6.9 inches (L.Y.) to 10.1 inches (R.H.) between these measures in the other subjects. The general pattern of change for all subjects except M.B., throughout phases 1 and 111, was toward a gradual reduction of these differences between measures. M.B. continued to show a 2.3 inch difference in measurements taken at the termination of phases 1 and 111.

The gains in muscle mass evidenced during the first eight weeks of training were not increased ober the five weeks of phase 11. In all cases a decline from Test 2 values, ranging from .1 to .6 inches (mean = -.3 ins.), was observed, but none of these decreases caused a reduction greater than .1 inches below the values initially determined in Test 1. Subject M.B. continued to increase his total gross circumference over phase 11 by .9 inches, while his muscular mass decreased .1 inches. An increase in limb skinfold fat of 12.8 mm. was also experienced by M.B. over these same five weeks.

Mean changes in gross and fat-corrected limb circumferences from Test 1 to Test 4 are reported below (N-6).

Figure VI
Changes in Body Dimensions

Total Limb Circumferences



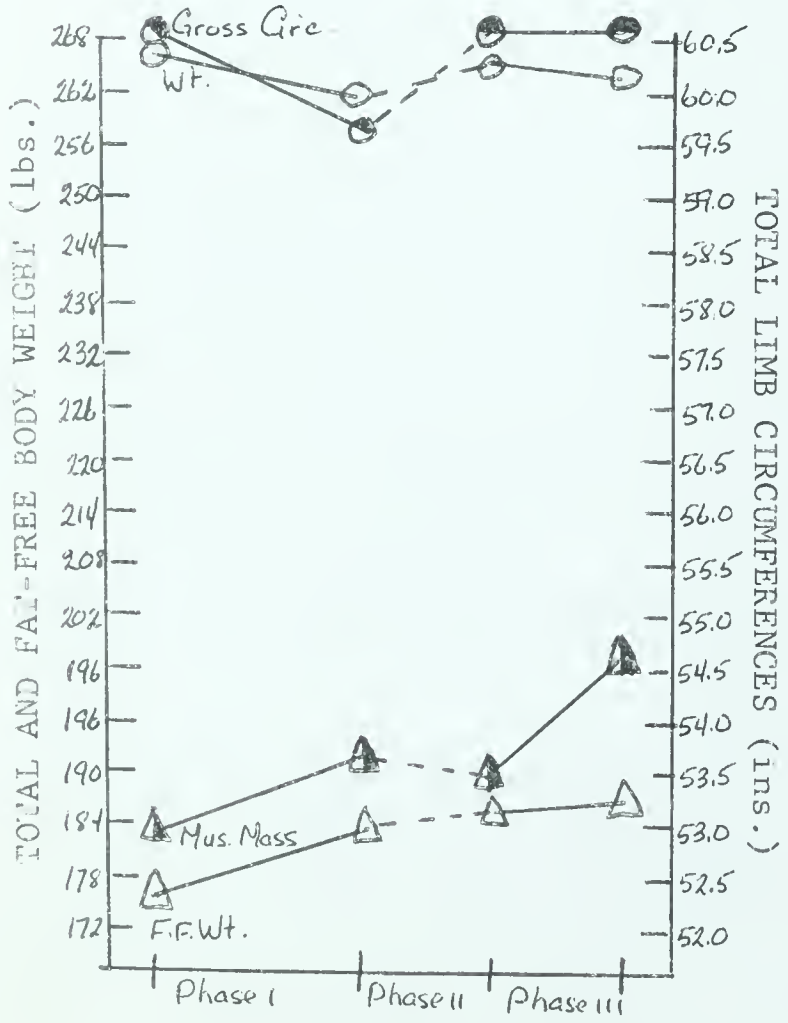
Analysis of Total Changes
by Individual Sites

Subject R.H. (35.0%)

Circumference(in)	Test1	Test2	Test3	Test4
1. Calf	16.6	16.6	16.6	17.1
2. Thigh	27.3	26.1	26.0	25.8
3. Thigh-Fat Correc.	21.0	21.1	21.0	21.3
4. Upper Arm	15.1	14.0	13.8	13.6
5. Upper Arm-Fat Correc.	11.3	11.5	11.2	11.4
6. Abdominal	44.1	40.2	41.5	39.3

Muscle Mass = 1. + 3. + 5.
Total Gross Circumference = 1.+ 2.+ 4.

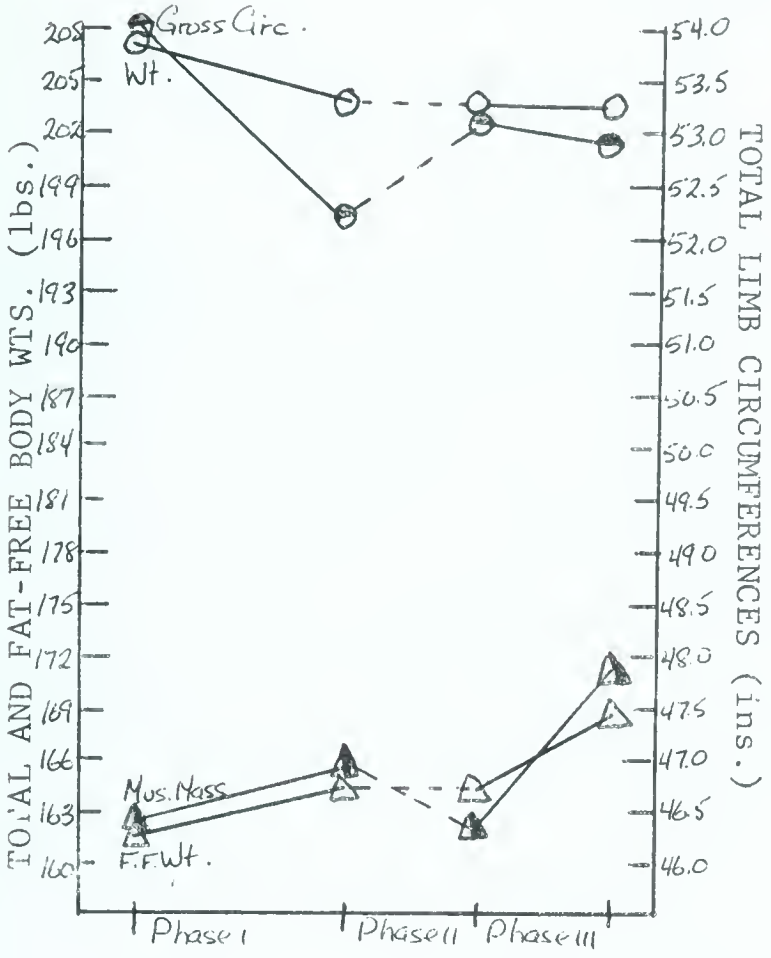
Subject C.B. (33.9%)



Circumference(in)	Test1	Test2	Test3	Test4
1. Calf	18.3	18.3	18.3	18.4
2. Thigh	26.0	25.3	26.3	26.3
3. Thigh-Fat Correc.	22.3	22.5	22.4	22.8
4. Upper Arm	16.3	16.0	16.1	16.1
5. Upper Arm-Fat Correc.	12.3	12.8	12.7	13.3
6. Abdominal	47.5	44.3	44.1	44.8

Figure V1 (Con't.)

Total Limb Circumferences



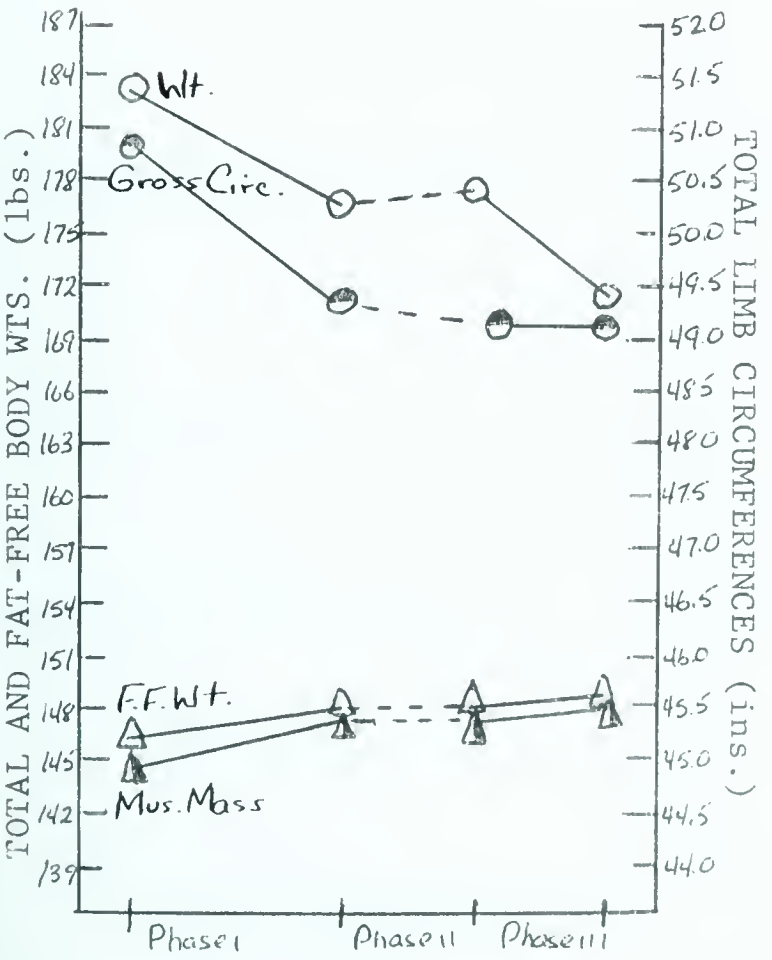
Analysis of Total Changes by Individual Sites

Subject M.G. (21.8%)

Circumference(in)	Test1	Test2	Test3	Test4
1. Calf	16.0	16.0	15.6	15.5
2. Thigh	24.0	22.8	24.2	23.9
3. Thigh-Fat Correc.	19.4	19.4	19.4	20.6
4. Upper Arm	13.8	13.4	13.3	13.4
5. Upper Arm-Fat Correc.	11.0	11.5	11.3	11.7
6. Abdominal	41.5	38.6	40.0	38.5

Total Muscle Mass = 1.+ 3.+ 5.
Total Gross Circumference = 1.+ 2.+ 4.

Subject G.H. (20.0%)



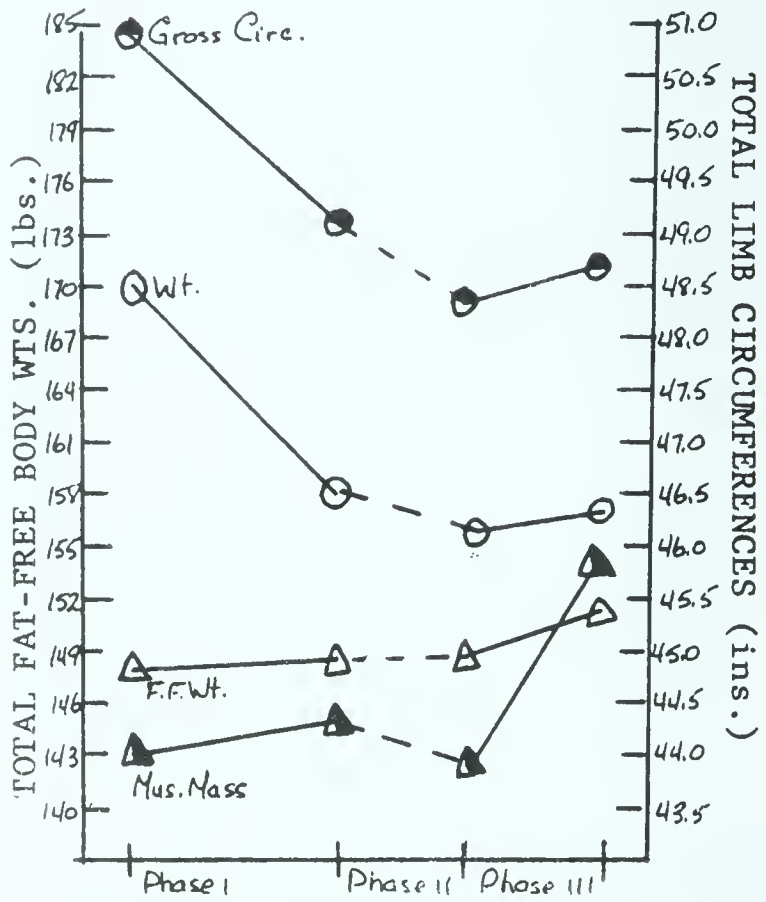
Circumference(in)	Test1	Test2	Test3	Test4
1. Calf	14.0	14.1	14.0	14.0
2. Thigh	23.2	22.1	21.8	22.0
3. Thigh-Fat Correc.	19.1	19.5	19.5	19.6
4. Upper Arm	13.6	13.1	13.3	13.1
5. Upper Arm-Fat Correc.	11.8	11.8	11.9	11.9
6. Abdominal	34.6	34.0	34.7	34.5

Figure V1 (Con't.)

Total Limb Circumferences

Analysis of Total Changes
by Individual Sites

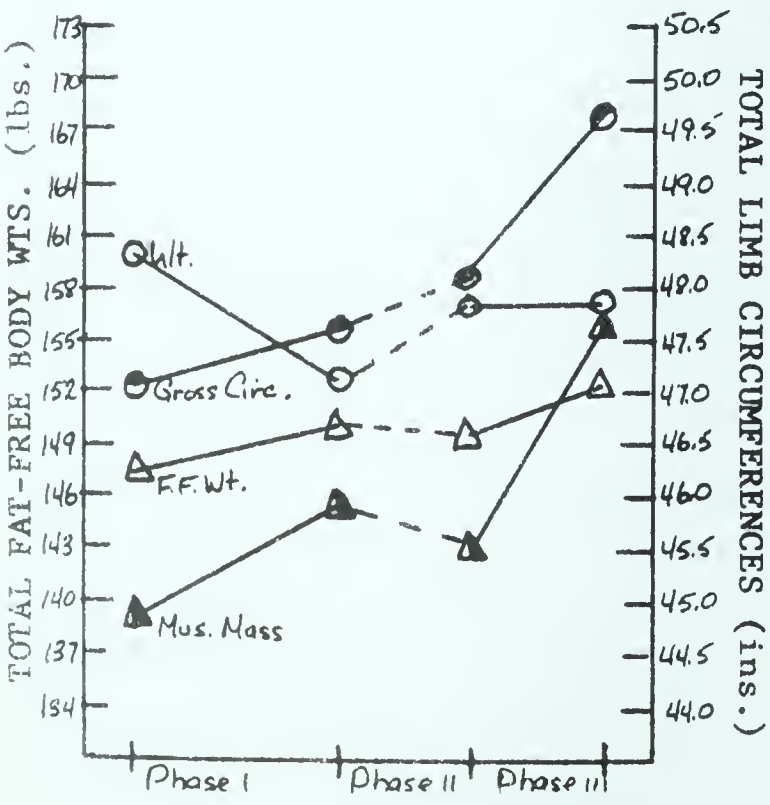
Subject L.Y. (13.2%)



Circumference(in)	Test1	Test2	Test3	Test4
1. Calf	14.5	14.3	13.9	14.0
2. Thigh	22.0	21.2	21.0	21.3
3. Thigh-Fat Correc.	17.4	17.7	17.7	19.3
4. Upper Arm	14.3	13.6	13.4	13.4
5. Upper Arm-Fat Correc.	12.1	12.3	12.3	12.4
6. Abdominal	35.3	33.8	33.0	33.3

Muscle Mass = 1.+ 3.+ 5.
Total Gross Circumference = 1.+ 2.+ 4.

Subject J.D. (7.9%)

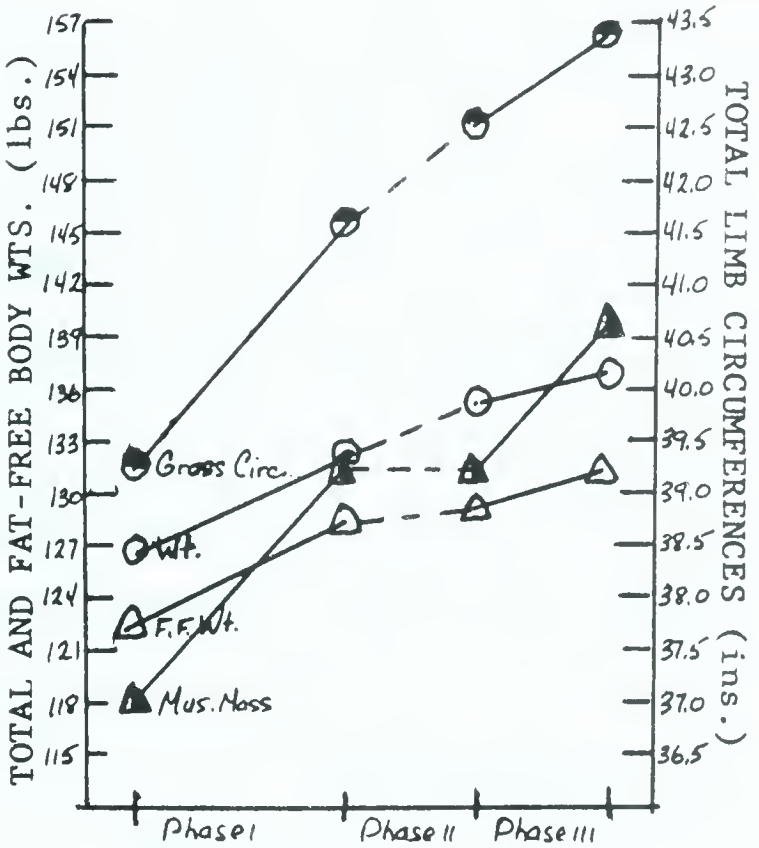


Circumference(in)	Test1	Test2	Test3	Test4
1. Calf	15.5	15.5	15.1	15.4
2. Thigh	20.5	19.1	20.2	21.3
3. Thigh-Fat Correc.	18.2	18.2	18.3	20.2
4. Upper Arm	12.1	13.0	12.9	12.9
5. Upper Arm-Fat Correc.	11.1	12.2	12.1	12.1
6. Abdominal	33.5	30.6	31.0	30.9

Figure VI (Con't.)

Subject M.B. (3.0%)

Total Limb Circumferences



Analysis of Total Changes
By Individual Sites

Circum. (in)	Test1	Test2	Test3	Test4
1. Calf	12.1	12.4	12.2	12.3
2. Thigh	16.4	18.1	19.0	19.3
3. Thigh-Fat Correc.	15.0	16.6	16.8	17.7
4. Upper Arm	10.8	11.1	11.3	11.4
5. Upper Arm-Fat Correc.	9.9	10.3	10.2	10.6
6. Abdominal	29.0	29.1	29.1	29.3



Measurement Site	Mean Change
Calf	-.13 ins.
Thigh	-1.30 ins.
Thigh (fat-corrected)	+1.40 ins.
Upper Arm	- .47 ins.
Upper Arm (fat-corrected)	+ .55 ins.

The thigh circumferences contributed more on the average than any other single measurement to both the mean reduction in total gross circumference and the mean increase in muscle mass. The gross circumference of the calf decreased an average of .50 inches in three subjects and showed a mean increase of .21 inches in the remaining three subjects.

Physiological Analysis

Mean Changes - Physiological Data. Mean changes in muscular strengths, treadmill performance time, basal metabolism, and body weight in kgs. from test to test are presented in Table XlV for the six originally overweight subjects. Cumulative changes from Test 1 through each of the following three tests are also presented, as a percentage of the initial values.

The following observations were drawn from an analysis of mean changes:

a) All measures, with the exception of basal oxygen intake in cc/min., changed significantly during both the first and final phases of the study.

b) Total Proportional Strength increased a total of 433 lbs. or 57.90 per cent of the initial mean value over the 18 weeks. After the first eight weeks of training, a 45.41 per

TABLE XIV

Mean Changes - Between Tests and as a Percentage of Initial Values - For Physiological Measures (N=6)

Measurement	Mean Changes - Raw Score and % of Initial Values			
	T1 - T2	T2 - T3	T3 - T4	T1 - T4
T.P.S. (lbs.)	+302**	-198*	+330**	+433**
% of initial	+45.41%	+16.98%	+57.90%	---
Strength / lb. wt.	+ 1.96**	- 1.19**	+ 1.98**	+2.70**
% of initial	+54.27%	+19.19%	+67.71%	---
Treadmill Performance Time (mins.)	+ 5.5 **	0	- 1.2	-6.7 **
% of initial	+60.32%	+61.62%	+70.06%	---
Basal Oxygen Intake (cc./min.)	- .03	- 4.3	+ 4.7	0
% of initial	- .12%	- 1.53%	- .06%	---
B.M.R. (cc./kg. wt.)	+ .16**	- .07	+ .10**	+ .19**
% of initial	+ 5.16%	+ 2.26%	+ 5.71%	---
B.M.R. (cc./kg. fat-free wt.)	- .06*	- .07*	+ .01	- .12*
% of initial	- 1.55%	- 3.26%	- 3.05%	---
Total Weight (kgs.)	- 4.78*	+ .12	- .92	-5.57*
% of initial	- 4.91%	- 4.62%	- 5.50%	---

* Sig. at .05 level; t=2.571
**Sig. at .01 level; t=4.032

cent increase was observed. The mean percentage increase from initial values in the strength per lb. of weight ratio, exceeded the T.P.S. increase by 8.86 per cent at Test 2 and by 9.81 per cent over all three phases.

c) The mean increases in Treadmill Performance Time showed the highest t values for all measures when computed for Phase 1 (t=7.646) and also over all three phases (t=7.966). A change of +1.2 minutes in performance time during Phase 111, was not significant at the .05 level of confidence (t=2.147).

d) The mean changes in B.M.R., expressed as cc/kg. weight, increased significantly (.01 level) during each of Phases 1 and 111 and over the entire 18 weeks. B.M.R. in cc/kg. of fat-free body weight decreased at the .05 level of significance during each of phases 1 and 11 and also at the termination of phase 111. Eighty four (84) per cent (.16) of the total increase (.19) in cc. O_2 per kg/wt. occurred during Phase 1. The total decrease in cc. O_2 per kg/fat-free weight (-.12) was divided almost equally between Phase 1 (-.06) and Phase 11 (-.07).

e) During the five weeks of Phase 11, three measures changed significantly on the average. Strength measures reversed the increases observed over the initial eight weeks and declined 28.43 per cent ($P<.05$) in T.P.S. and 35.08 per cent ($P<.01$) in strength per lb./wt. ratio from the Test 2 values. The decrease observed during Phase 1 (-.06) in cc. O_2 per kg/fat-free weight continued during Phase 11 (-.07) and these decreases were both significant at the .05 level of confidence. Mean treadmill performance time remained steady at the Test 2 finding of 17.3

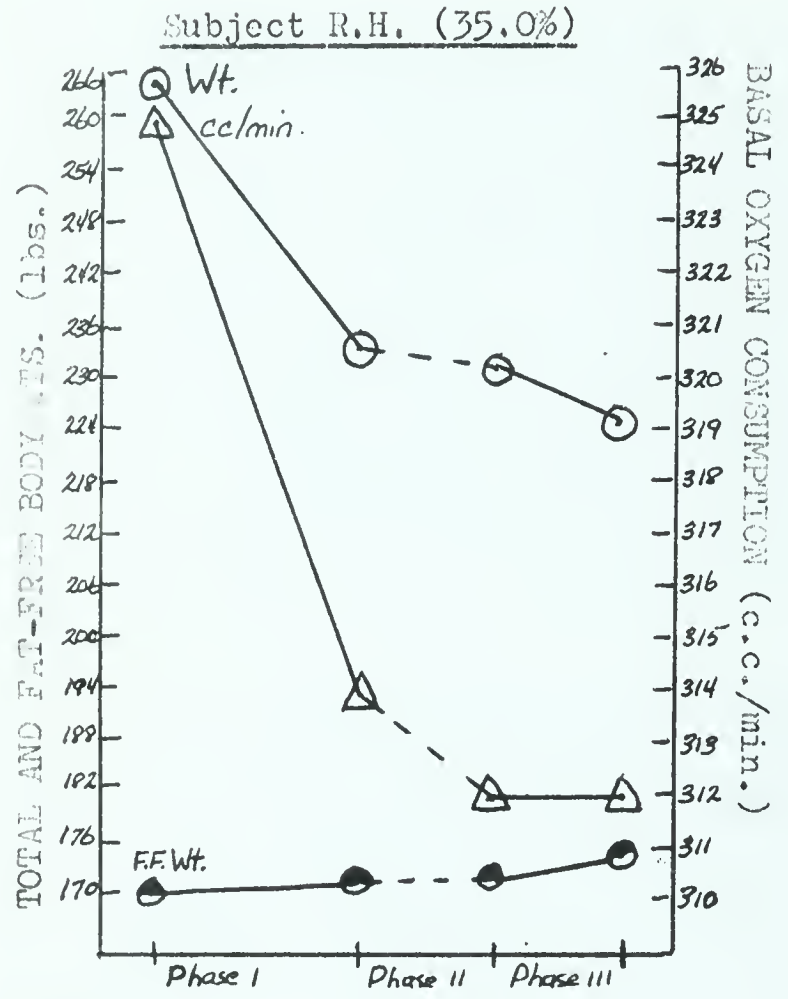
minutes 5.5 minutes above the initial value. None of the mean changes in either direction during Phase 11 was sufficient to offset completely the changes observed during Phase 1. An analysis of the cumulative percentage changes at Test 3 shows that average changes in basal O_2 in cc./min. and cc./kg. of weight, and in treadmill performance to a lesser extent, continued to change in the direction observed in the initial phase.

Individual Changes in B.M.R. Individual changes in basal oxygen intake, cc./min., are plotted against changes in total and fat-free body weights in Figure V11. Oxygen intake, at each of the four testing periods, is also described in terms of both the weight and fat-free weight indicies.

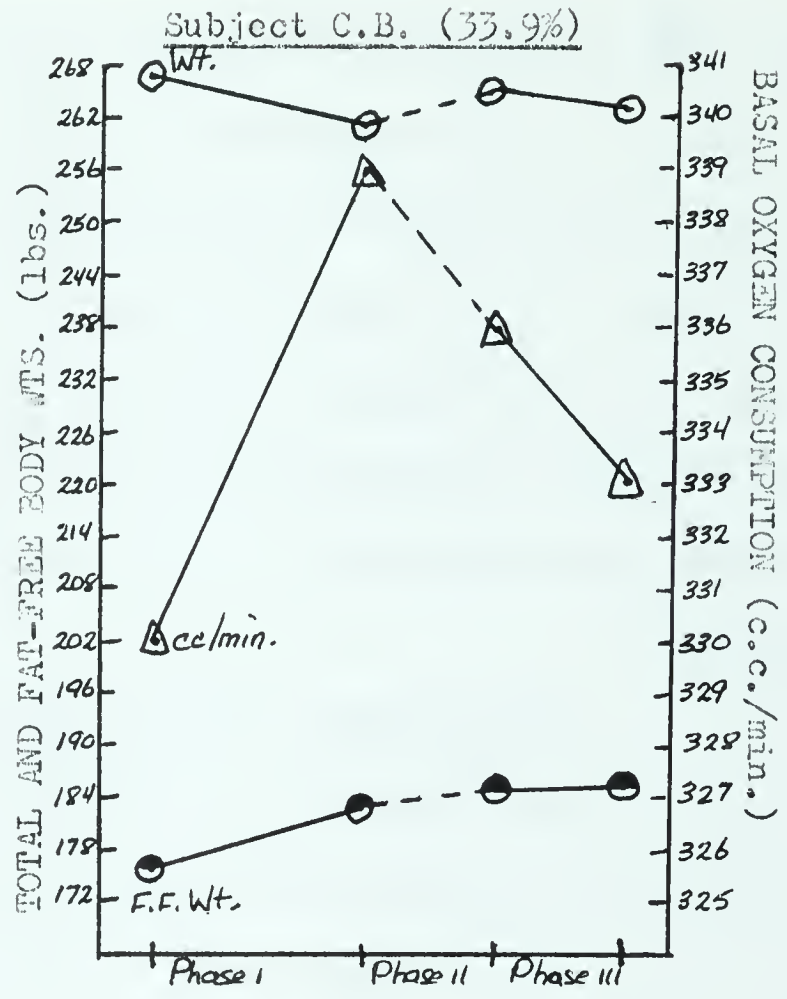
Only two subjects, M.G. and M.B., demonstrated an increase in basal oxygen consumption (cc./min.) throughout both phases 1 and 111. All subjects increased their basal oxygen consumption during Phase 111 from 3 (M.B.) to 13 (J.D.) cc./min. with the exception of C.B. who declined 3 cc./min. over this five week period.

B.M.R. in cc./kg. weight increased in all subjects during Phases 1 and 111. The mean decreases shown in cc. O_2/kg. fat-free weight, however, were not contributed to by all subjects. During Phase 1, M.G. maintained his Test 1 ratio of 3.95 and M.B. increased his initial value 2.37 per cent, from 4.35 to 4.45. Subjects G.H., L.Y., and J.D. increased their ratios, .05 in the first two cases and .10 with the latter case, over the final five weeks. C.B. and R.H. continued to decrease

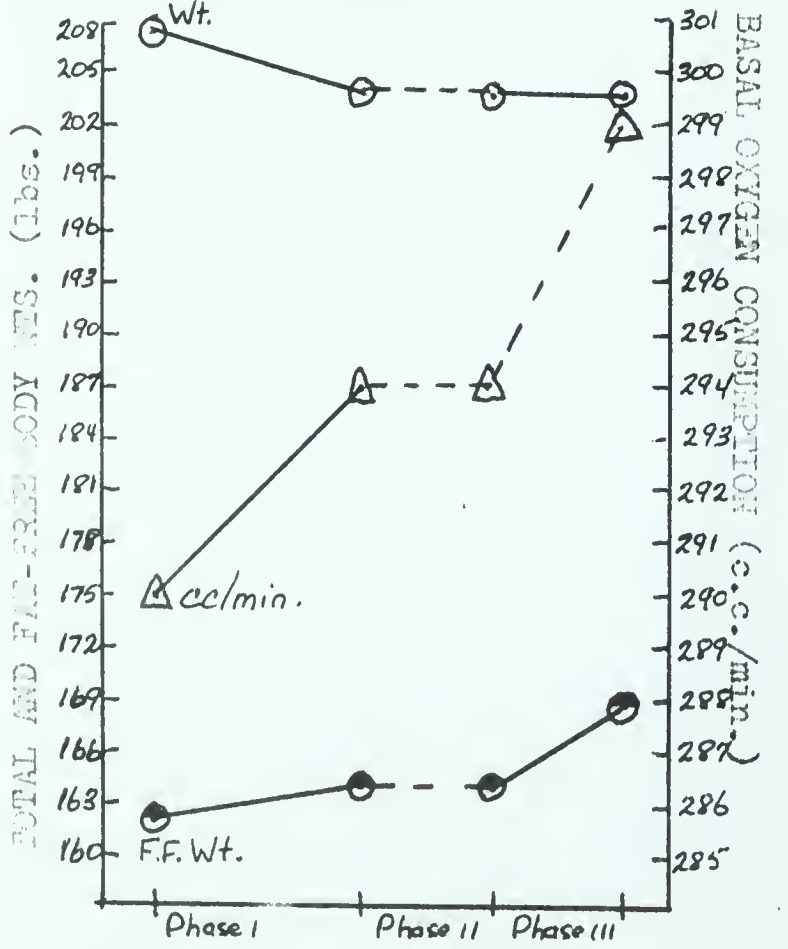
Figure VII
Changes in Basal Metabolism



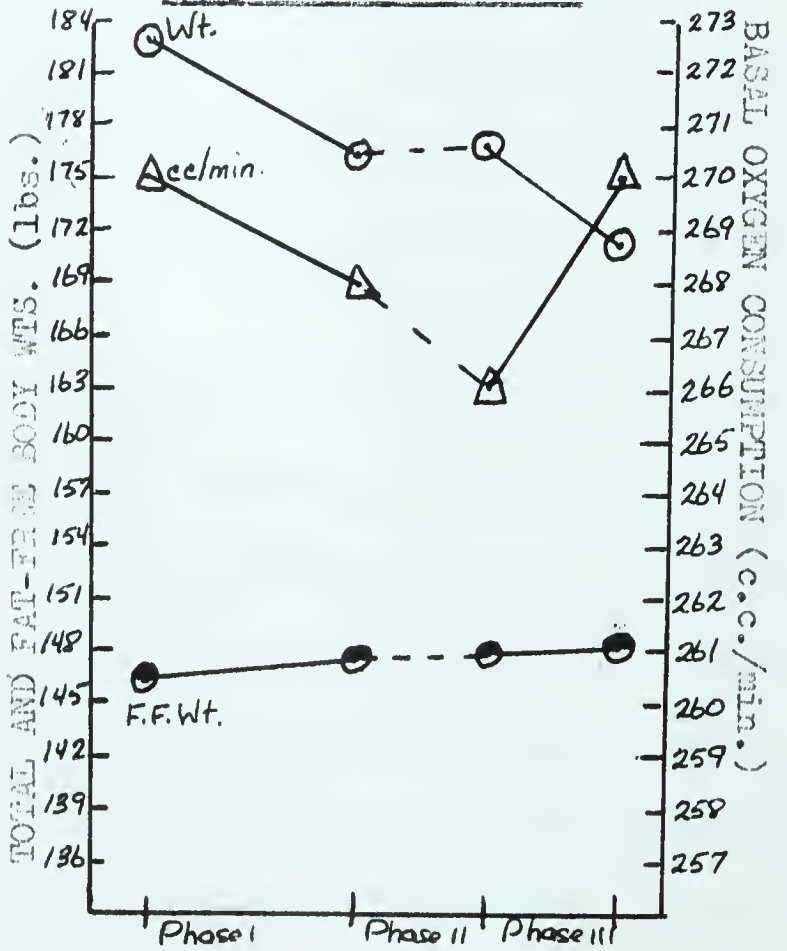
c.c/kg.wt.	2.71	2.95	2.97	3.05
c.c/kg.F.F.wt.	4.17	4.02	3.97	3.91



	2.73	2.86	2.79	2.78
	4.14	4.08	4.00	3.95



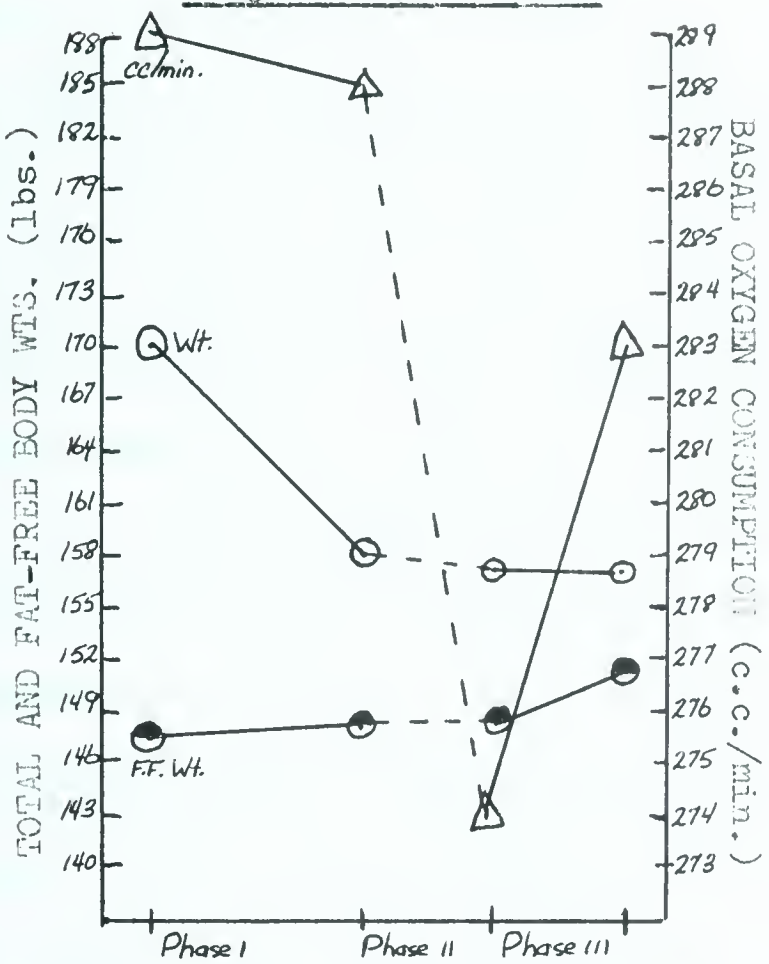
c.c/kg.wt.	3.09	3.18	3.18	3.23
c.c./kg.F.F.wt.	3.95	3.95	3.95	3.91



	3.25	3.34	3.32	3.48
	4.07	4.01	3.97	4.02

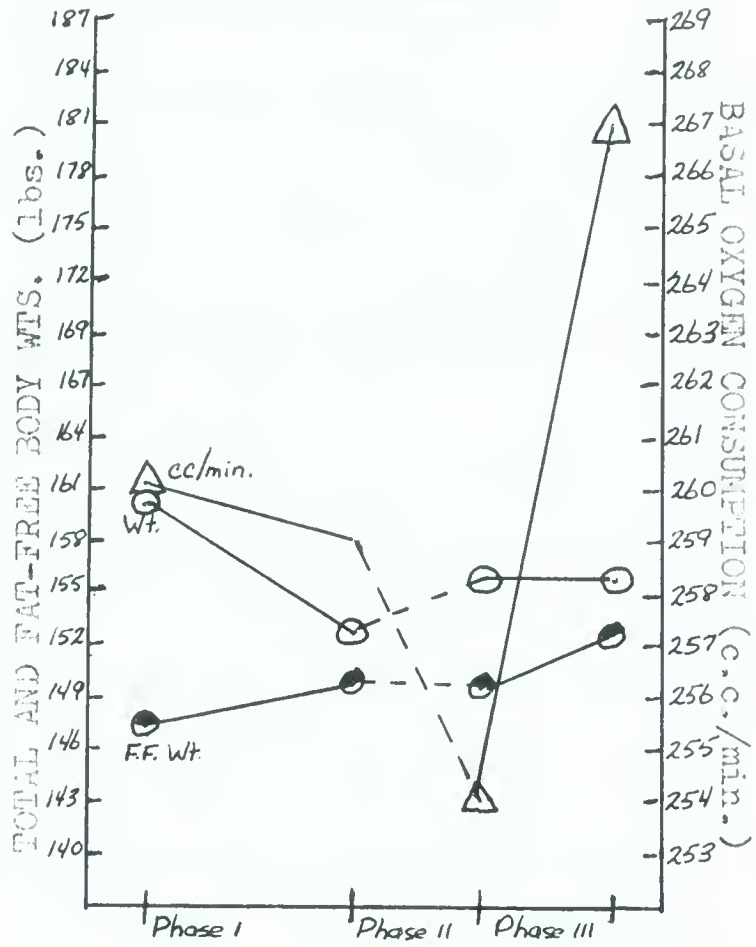
Figure VII (Con't.)

Subject L.Y. (13.2%)



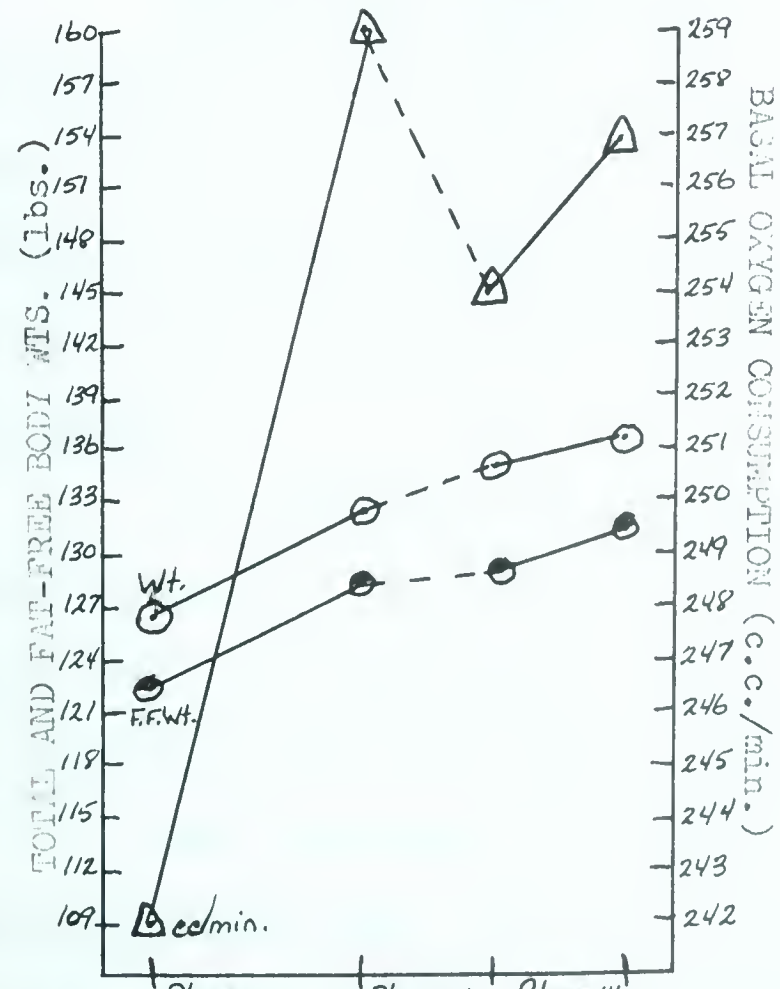
	Phase I	Phase II	Phase III	
c.c./kg.wt.	3.75	4.02	3.85	3.93
c.c./kg.F.F.wt.	4.32	4.29	4.08	4.13

Subject J.D. (7.9%)



	Phase I	Phase II	Phase III	
	3.58	3.94	3.57	3.75
	3.89	3.81	3.76	3.86

Subject M.B. (3.0%)



	Phase I	Phase II	Phase III	
c.c./kg.wt.	4.22	4.32	4.14	4.15
c.c./kg.F.F.wt.	4.35	4.45	4.33	4.31

.05 and .06 respectively during Phase 111, but these changes were below the decreases observed over the initial eight weeks. Subject M.G. presents a completely different pattern from the remainder of the group in that his ratio declined .04 or 1.01 per cent of the initial value during Phase 111 after having remained steady over the first two phases.

During Phase 11, five of the seven subjects decreased in all three B.M.R. ratios regardless of the type of change experienced in Phase 1 with R.H. and M.G., however, changes in cc. O_2/kg. weight established in Phase 1 were continued, to a lesser extent, during Phase 11. The greatest total changes in cc. O_2 per kg.wt. (-12.55%) and per kg./fat-free weight (-6.24%) were observed with subject R.H., while M.B. showed the greatest increase (7.02%) in O_2 intake in cc./min.

Individual Changes in Strength. Changes in Total Proportional Strength are plotted against body and fat-free weight changes in Figure V111 for individual subjects. Test results for each strength measure are also shown along with calculations of T.P.S. per lb. of body weight and per lb. of fat-free weight.

All subjects conform generally to the pattern of change indicated by the means in that T.P.S., in absolute terms as well as per unit of both weights, increased during phases 1 and 111 and decreased over the middle five weeks.

The decreases in strength observed during Phase 11 were sufficient only in subject M.G. to erase the gains shown over the initial phase. The results of Test 2 reveal that this

subject had decreased .40, 1.08 and 1.50 per cent below his initial values for T.P.S., strength/lb. wt. and strength/lb. fat-free weight, respectively.

The greatest increases, as a percentage of the initial values, were found with R.H. in T.P.S. (119.66%), strength/lb. of wt. (156.93%) and strength per lb. of fat-free weight (114.47%). This subject had the lowest initial values in all of these measures. M.G. increased the least in all of his strength measures (23.56% in T.P.S.) and also scored the highest of any subject in his T.P.S. initially.

The average increase in each of the four strength measurements over the entire 18 weeks, along with the percentage contribution of each of the changes to the mean change in T.P.S. are presented in Table XV for all subjects.

TABLE XV

Contribution of Individual Strength Tests to Increase in Total Proportional Strength (N=7)

Strength Measure	Mean Increase (T1-T4)	% of Mean Increase in T.P.S.
Back Lift	136 lbs.	27.6%
Leg Lift	341 lbs.	70.2%
Right Grip	3 lbs.	.7%
Left Grip	7 lbs.	1.5%
T.P.S.	487 lbs.	100%

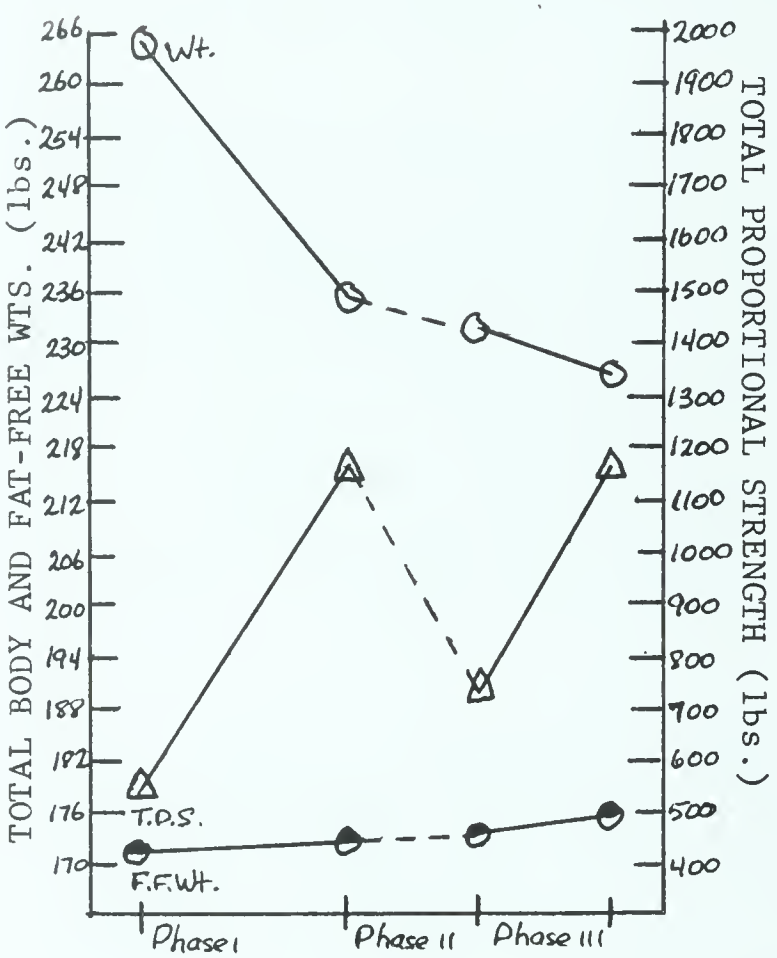
The mean increase in Leg lift accounted for 70.2 per cent of

Figure V111
Changes in Muscular Strength

Total Proportional Strength

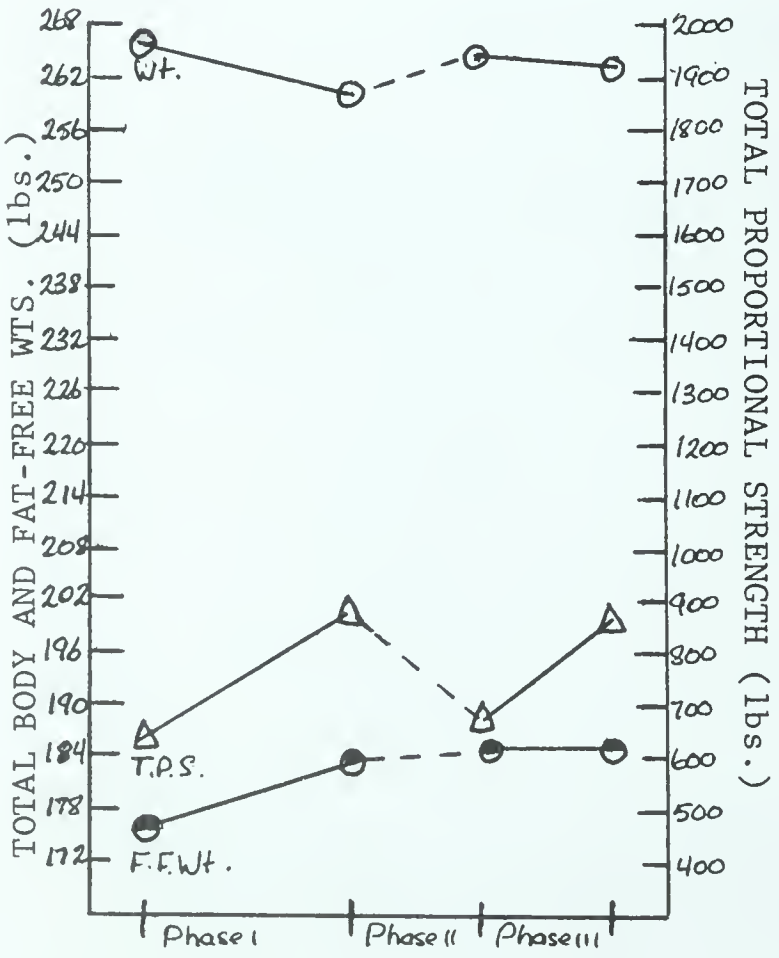
Analysis of Total Change by Muscle Groups

Subject R.H. (35.0%)



Strength Test (lbs.)	Test1	Test2	Test3	Test4
Back Lift	130	260	240	360
Leg Lift	215	700	270	600
Right Grip	89	92	118	95
Left Grip	100	111	100	118
Str./lb. Wt.	2.02	4.95	3.14	5.19
Str./lb. F.F.Wt.	3.11	6.74	4.19	6.67

Subject C.B. (33.9%)

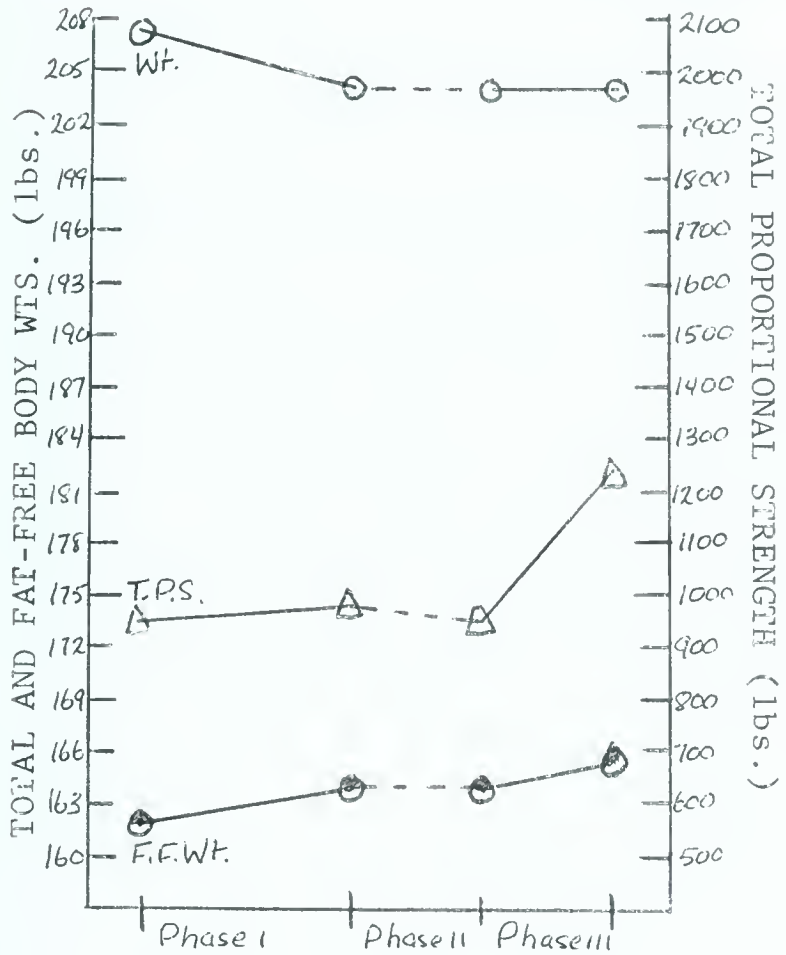


Strength Test (lbs.)	Test1	Test2	Test3	Test4
Back Lift	140	270	230	270
Leg Lift	250	400	230	390
Right Grip	108	114	120	110
Left Grip	129	83	80	92
Str./lb. Wt.	2.37	3.34	2.49	3.27
Str./lb. F.F.Wt.	3.56	4.73	3.56	4.64

Figure V111 (Con't.)

Total Proportional Strength

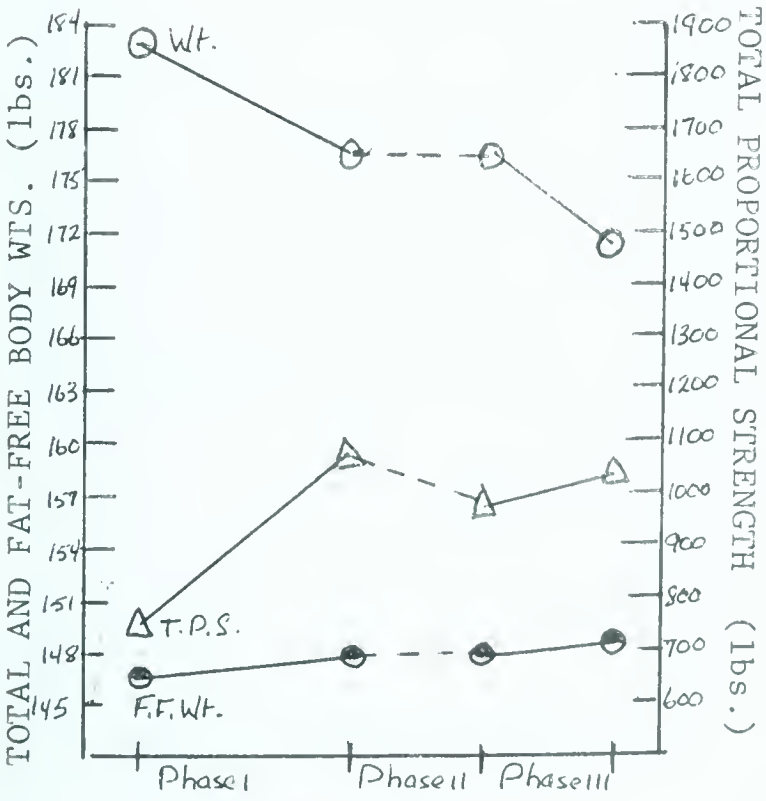
Subject M.G. (21.8%)



Analysis of Total Change by Muscle Groups

Strength Test (lbs.)	Test1	Test2	Test3	Test4
Back Lift	210	270	360	310
Leg Lift	510	490	380	670
Right Grip	133	120	115	130
Left Grip	104	108	98	122
Str./lb. Wt.	4.62	4.83	4.67	6.03
Str./lb. F.F.Wt.	5.90	6.02	5.81	7.29

Subject G.H. (20.0%).



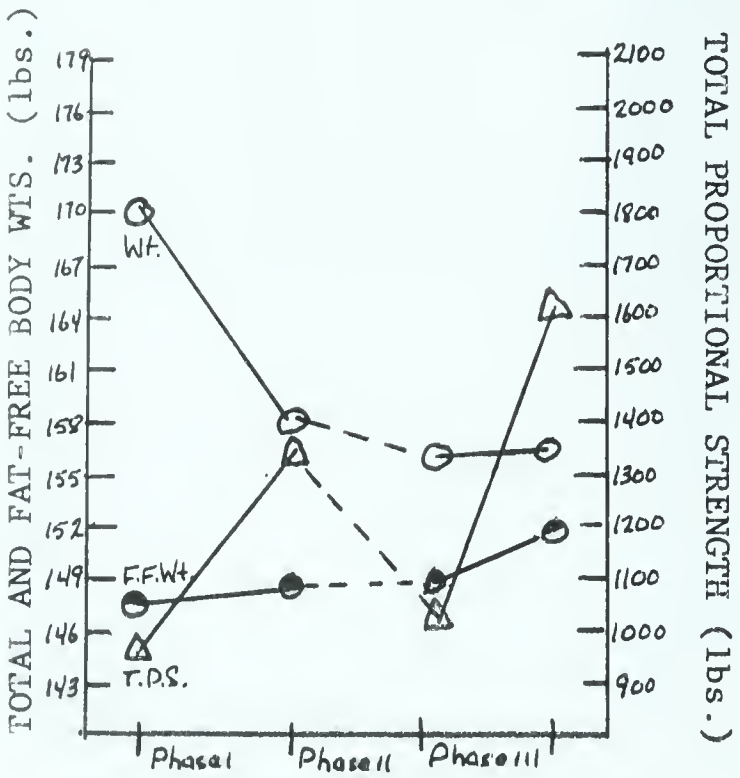
Strength Test (lbs.)	Test1	Test2	Test3	Test4
Back Lift	100	250	260	210
Leg Lift	440	550	460	580
Right Grip	132	136	130	119
Left Grip	82	120	105	103
Str./lb. Wt.	4.13	5.98	5.40	5.92
Str./lb. F.F.Wt.	5.15	7.16	6.45	6.83

Figure V111 (Con't.)

Total Proportional Strength

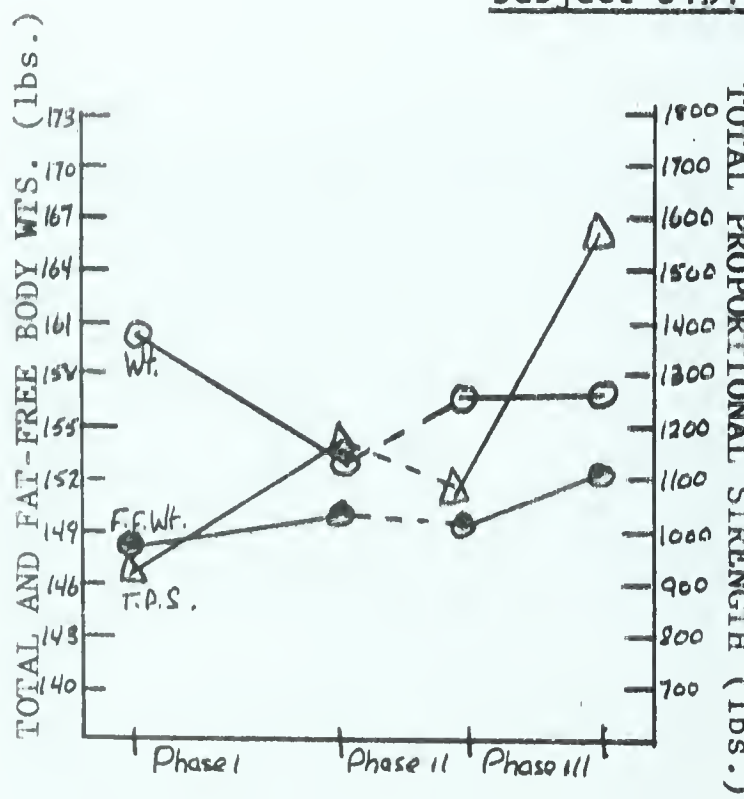
Analysis of Total Change by Muscle Groups

Subject L.Y. (13.2%)



Strength Test (lbs.)	Test1	Test2	Test3	Test4
Back Lift	240	480	270	300
Leg Lift	300	850	490	1,050
Right Grip	142	120	130	140
Left Grip	100	120	124	130
Str./lb. Wt.	5.66	8.79	6.51	10.32
Str./lb. F.F.Wt.	6.52	9.39	6.84	10.71

Subject J.D. (7.9%)



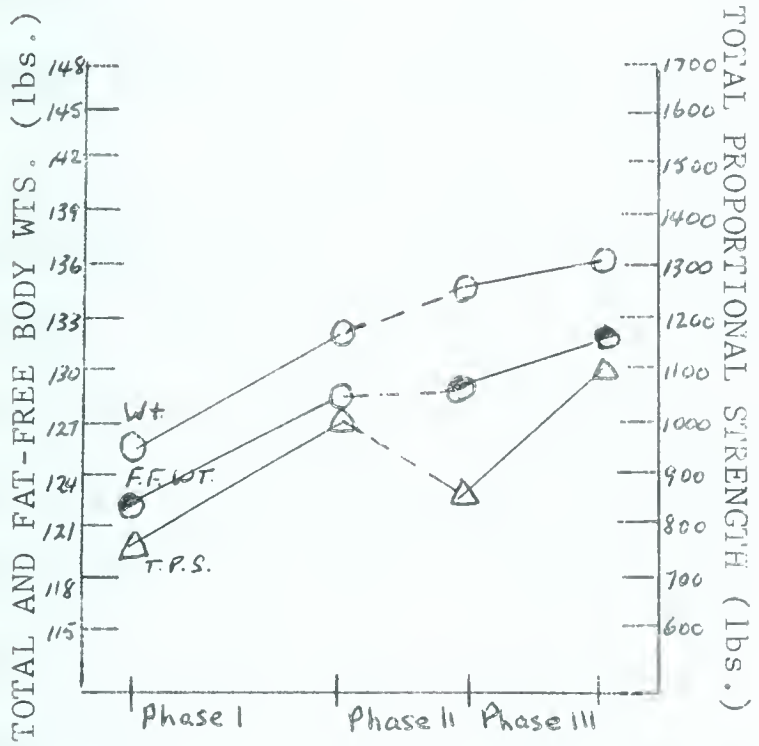
Strength Test (lbs.)	Test1	Test2	Test3	Test4
Back Lift	275	290	290	395
Leg Lift	430	500	430	950
Right Grip	105	102	100	110
Left Grip	89	100	100	105
Str./lb. Wt.	5.74	7.75	6.31	9.30
Str./lb. F.F.Wt.	6.24	7.89	7.31	9.57

Figure V111 (Con't.)

Total Proportional Strength

Analysis of Total Change by Muscle Groups

Subject M.B. (3.0%)



Strength Test (lbs.)	Test1	Test2	Test3	Test4
Back Lift	150	300	230	305
Leg Lift	430	500	430	690
Right Grip	109	112	112	116
Left Grip	100	96	96	98
Str./lb. Wt.	6.23	7.60	6.42	8.82
Str./lb.F.F.Wt.	6.44	7.86	6.71	9.18

the increase in T.P.S. with the Leg and Back Lifts combined contributing 97.8 per cent to the total mean change.

Individual Changes - Treadmill Performance. Figure IX contains graphical illustrations of changes in treadmill performance as plotted against changes in body and fat-free body weights and per cent body fat.

All subjects experienced their greatest gains in treadmill performance time during the initial eight weeks of the study. During Phase II, all subjects remained steady at their respective levels determined in Test 2 except L.Y. who decreased .5 minutes and R.H. who added one more minute. All subjects, excluding C.B. who remained steady, increased from Test 3 to Test 4. Only G.H. and L.Y., however, showed similar patterns of increase to those observed during the first phase, by increasing their performance times 2.5 and 3 minutes respectively over the final five weeks.

G.B. demonstrated the greatest total change in performance time with an increase of 145.45 per cent above the initial value. This subject's total increase in time of eight minutes, however, was duplicated by subjects L.Y., G.H. and M.B. M.G. and J.D. were found to have the smallest total increases in performance time, which were equal to 4 and 4.5 minutes respectively.

The final results of selected measurements for all subjects are presented in Table XVI. Mean values, reported for college men, are also presented for purposes of comparison. Photographs, taken at Tests 1, 2 and 4, are shown in the Appendix.

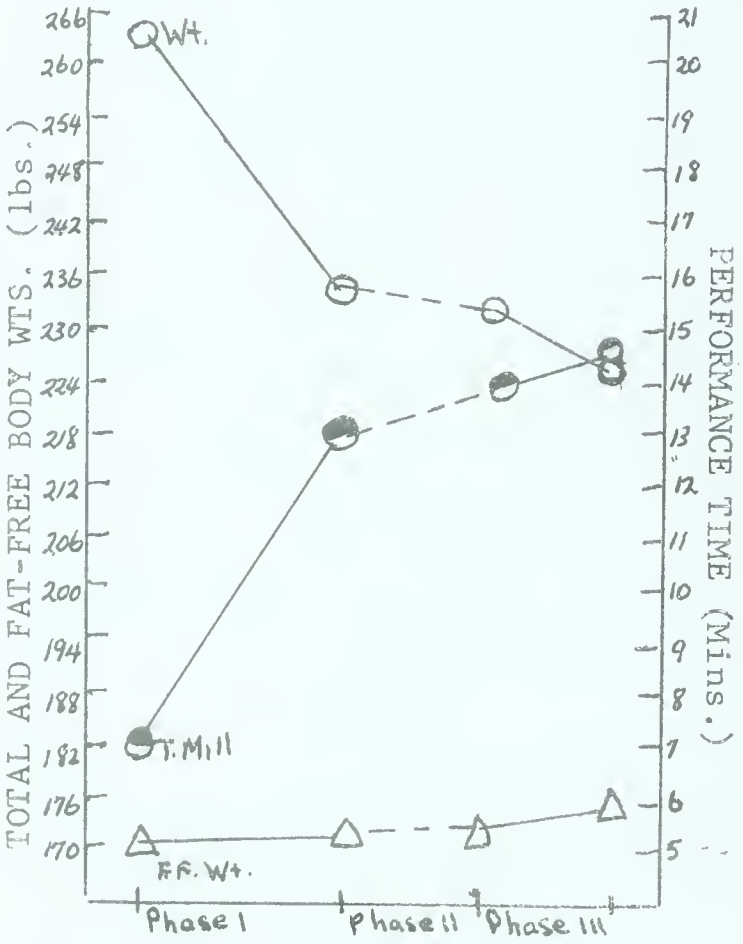
Figure 1X

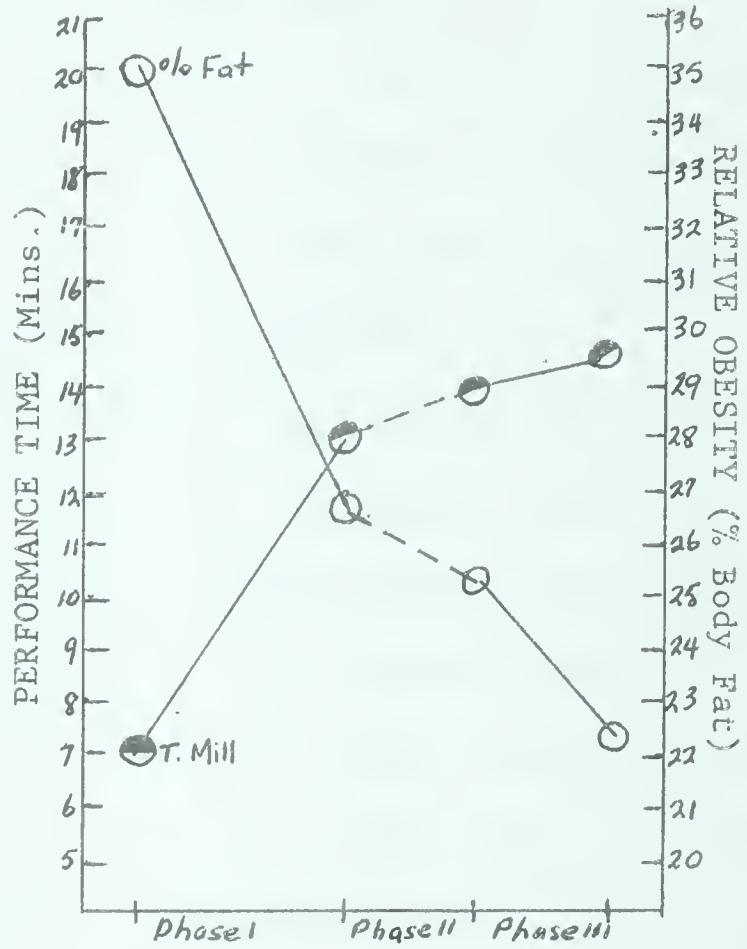
Changes in Treadmill Performance

Performance Time
Wt. and Fat-Free Wt.

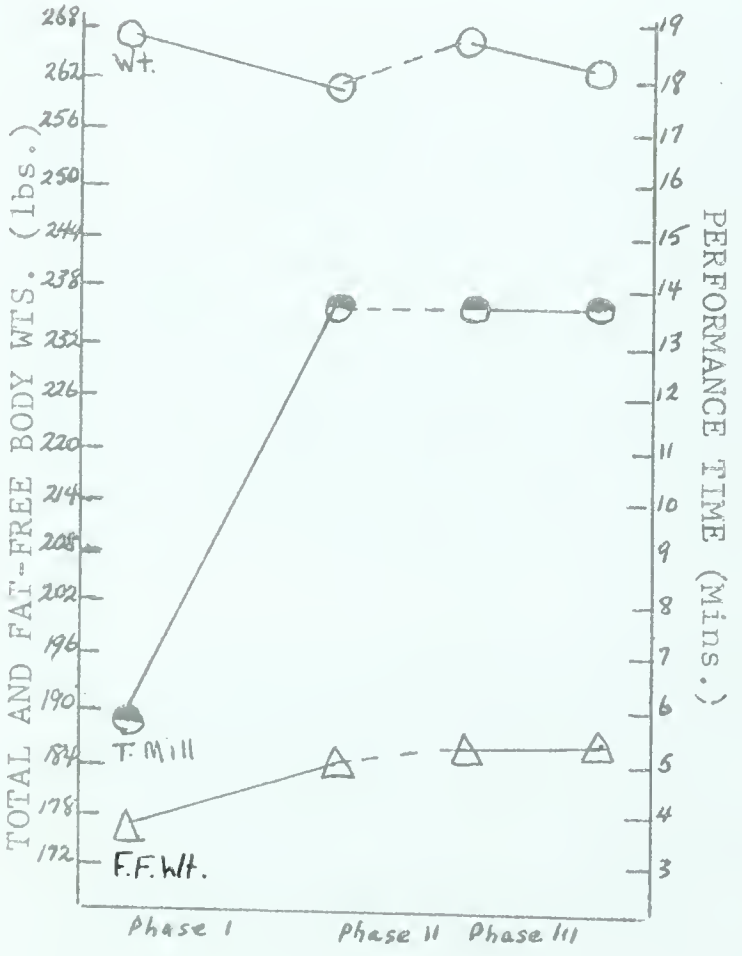
Performance Time
and
Relative Obesity

Subject R.H. (35.0%)





Subject C.B. (33.9%)



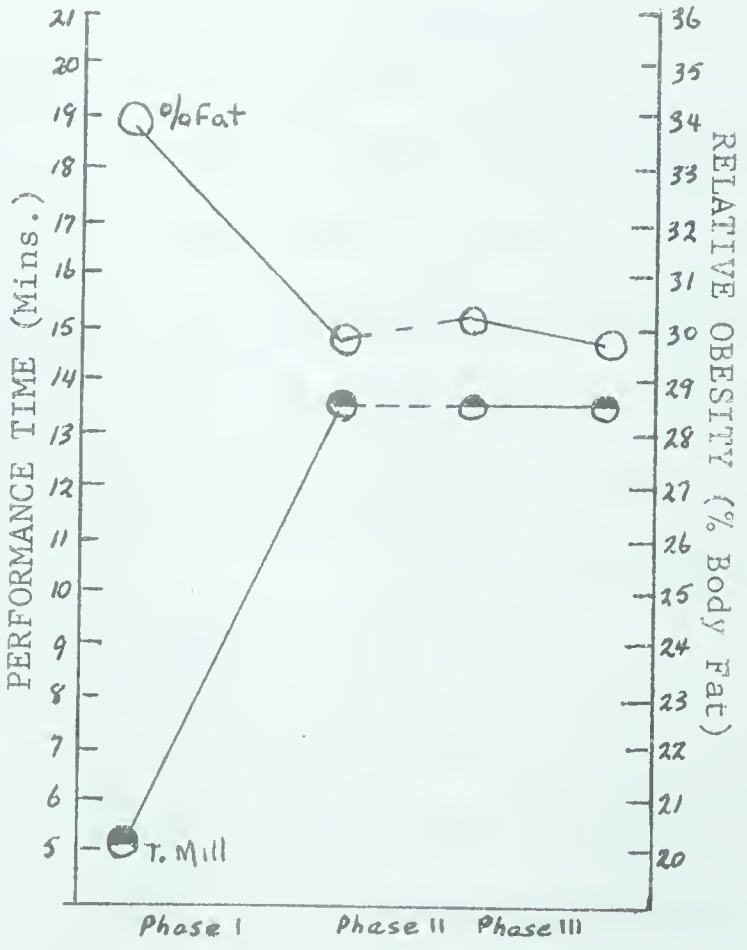
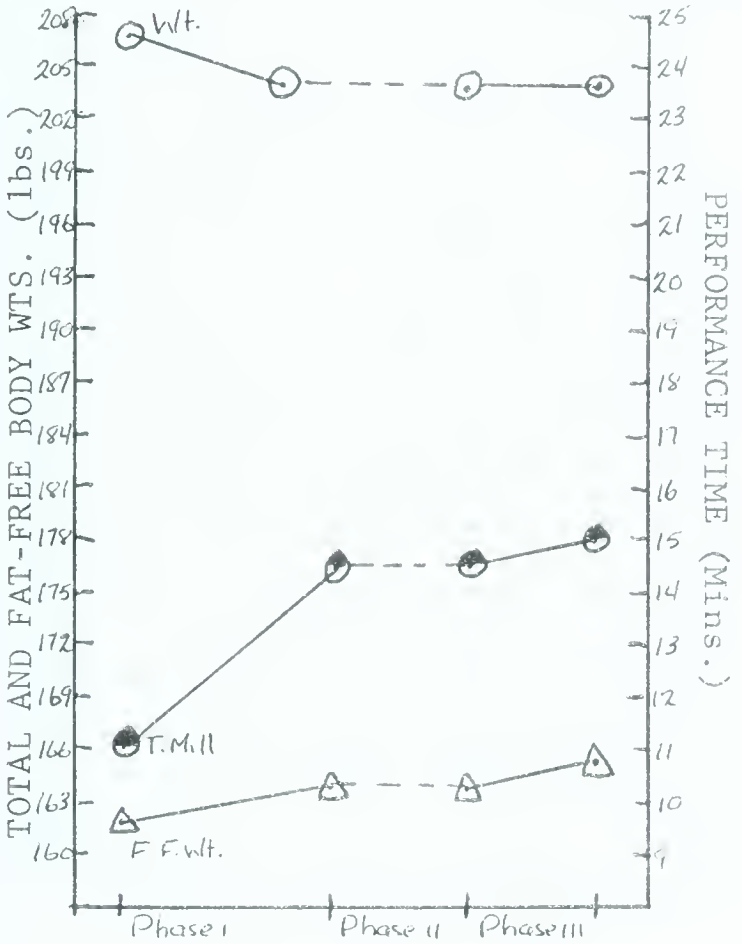


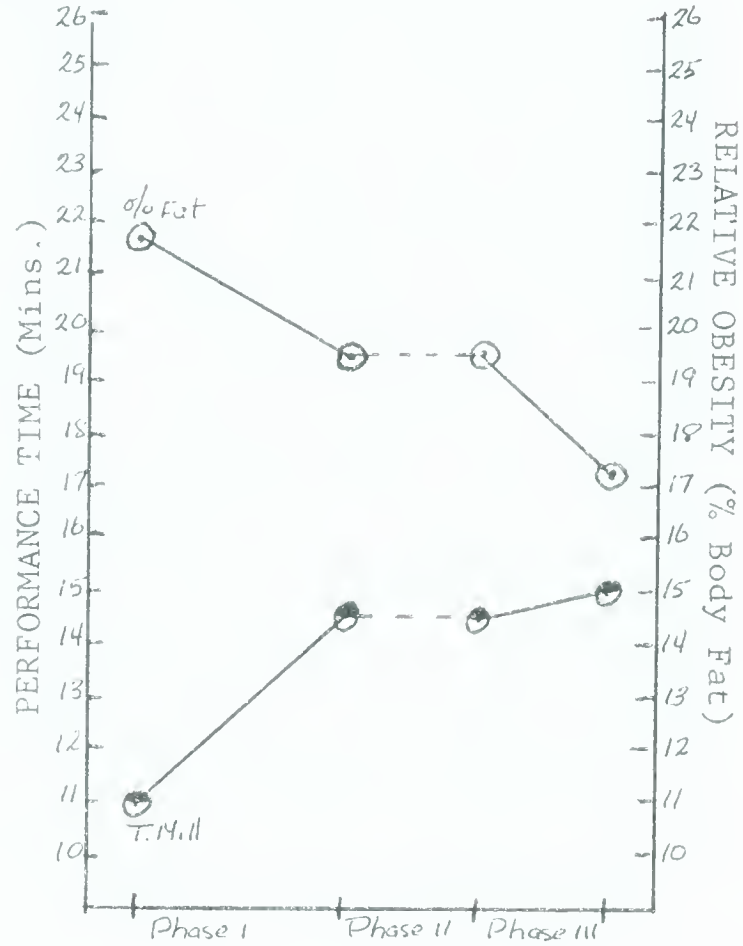
Figure 1X (Con't.)

Performance Time
Wt. and Fat-Free Wt.

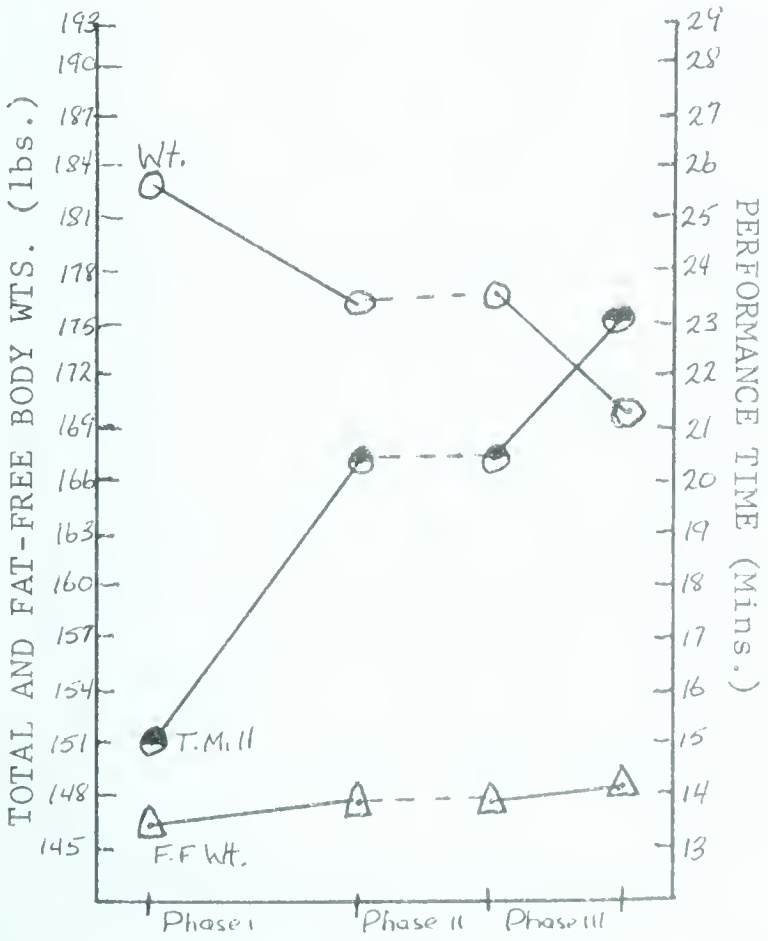
Subject M.G. (26.8%)



Performance Time
and
Relative Obesity



Subject G.H. (20.0%)



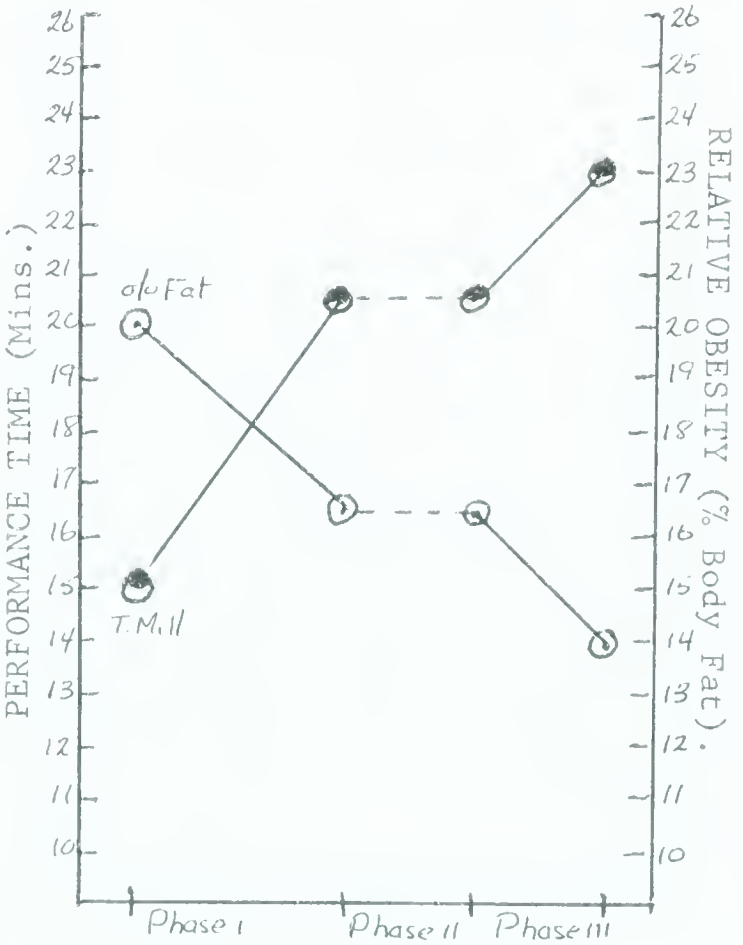
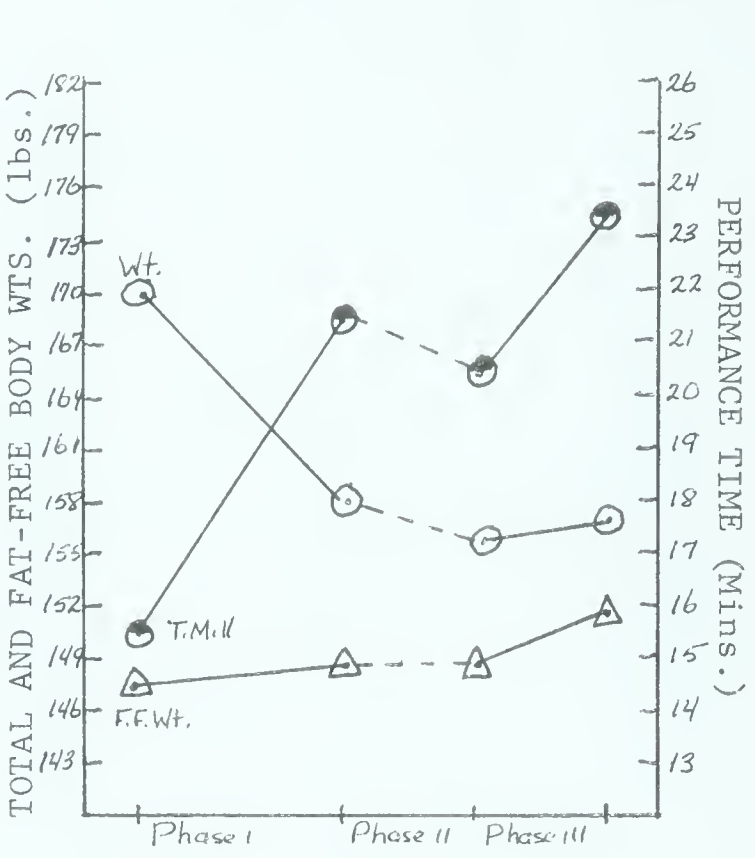


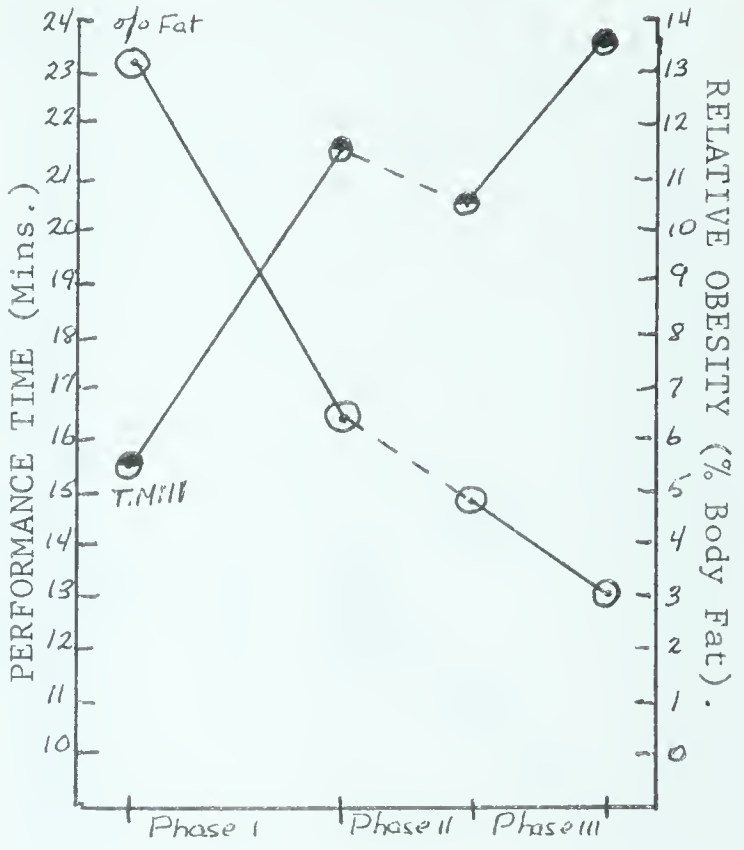
Figure 1X (Con't.)

Performance Time
Wt. and Fat-Free Wt.

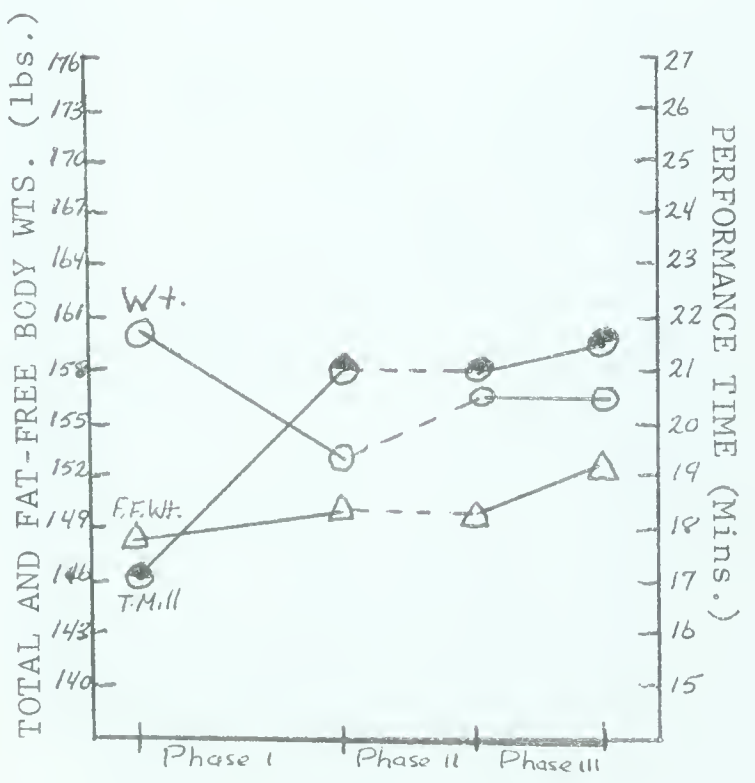
Performance Time
and
Relative Obesity

Subject L.Y. (13.2%)





Subject J.D. (7.9%)



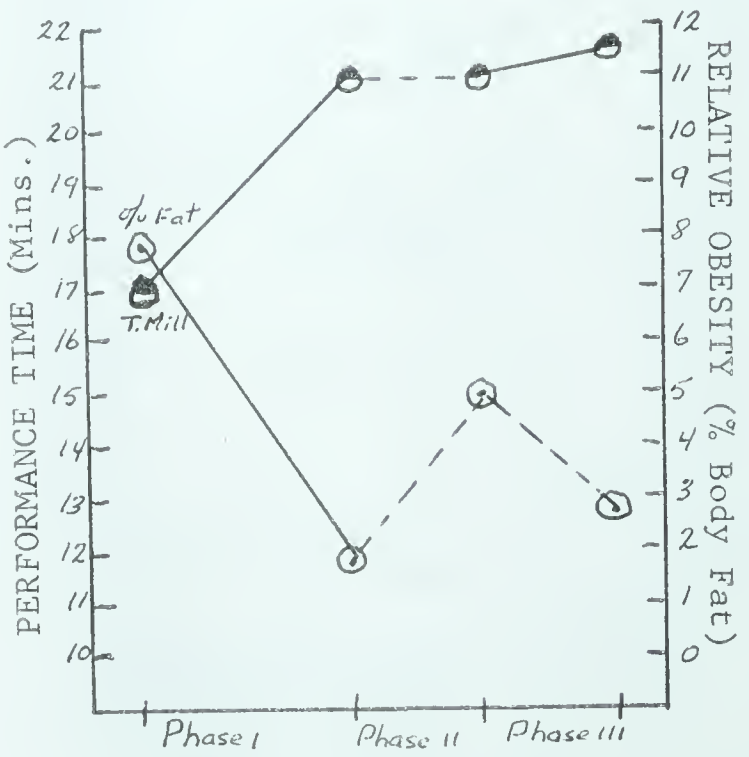


Figure 1X (Con't.)

Performance Time
Wt. and Fat-Free Wt.

Performance Time
and
Relative Obesity

Subject M.B. (3.0%)

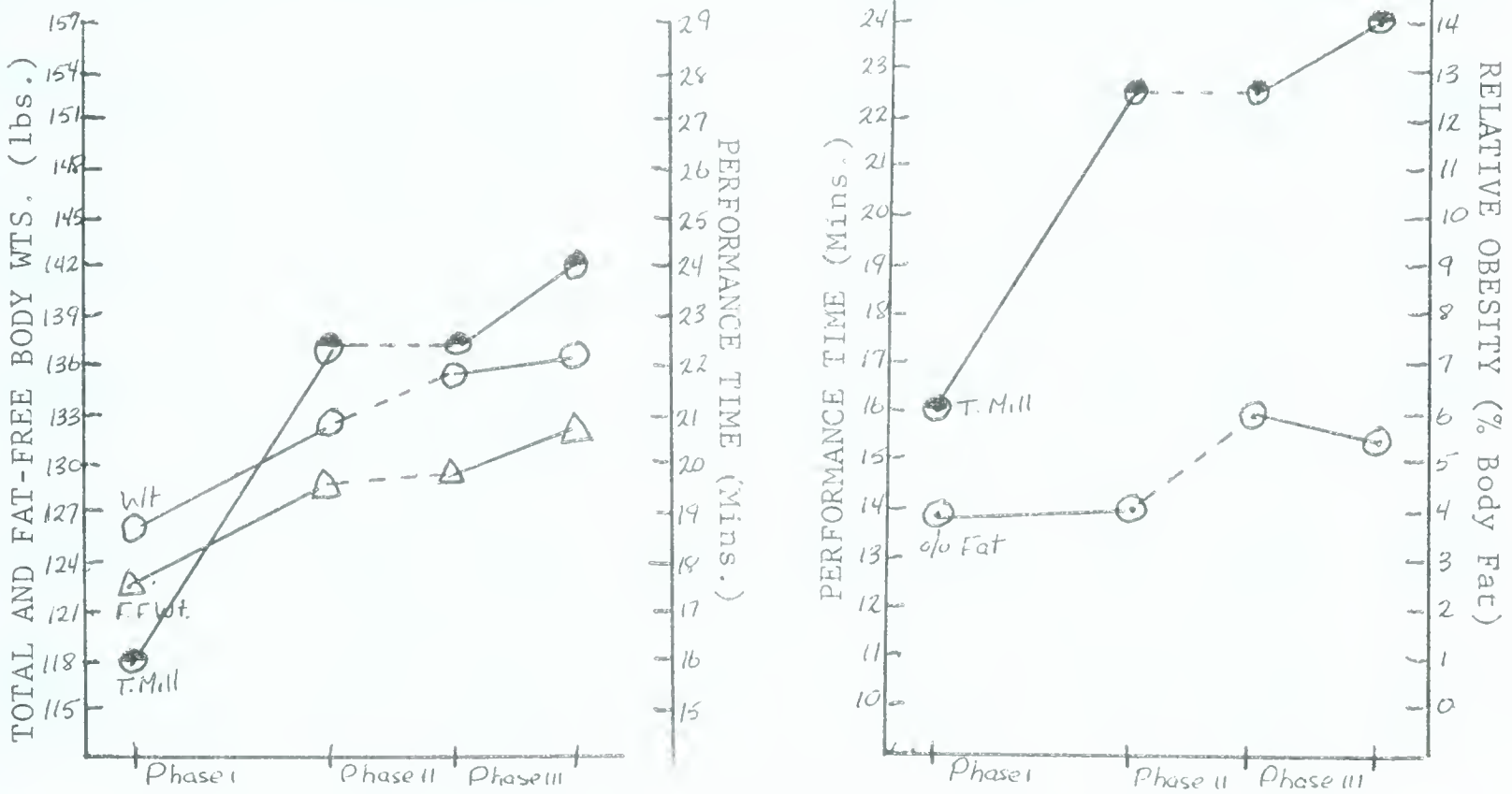


Table XVI

Final Values of Selected Measures for Each Subject
(N = 7)

Selected Measures	R.H.	C.B.	M.G.	G.H.	L.Y.	J.D.	M.B.	- Mean - College Men
Total Body Wt. (lbs.)	226.0	264.0	204.0	171.0	157.0	157.0	137.0	174.68 a 168.40 b
Relative Body Wt. (%)	157	159	130	101	105	99	84	100 c
% Body Fat (%)	22.2	29.6	17.2	13.9	3.0	2.8	3.9	9.89 a 10.68 b
Fat-Free Wt. (lbs.)	175.83	185.86	168.92	148.09	151.29	152.61	131.66	155.19 a 150.20 b
Total Proportional Strength (lbs.)	1173	862	1232	1012	1620	1460	1209	1097 d
Str./lb. wt.	5.19	3.27	6.03	5.92	10.32	9.87	9.18	6.74 d
Treadmill Performance Time (mins.)	14.5	13.5	15.0	23.0	23.5	21.5	24.0	15.8 e
Basal O_2 Intake: Per kg. wt. (c.c./kg.)	3.05	2.78	3.23	3.48	3.98	3.75	4.15	3.41 a 3.91 f
Basal O_2 Intake: Per kg. fat-free wt. (c.c./kg.)	3.91	3.95	3.91	4.02	4.13	3.86	4.31	3.89 a 4.17 f
Basal O_2 Intake: % of "Standard" B.M.R. (%)	98	100	100	102	112	104	103	102 a

a Dempsey (1963) N = 50 b Yuhasz (1962) N = 116 c Pett (1955) d Yuhasz (196

e Correlation Study N = 34 f Von Dobeln (1956) N = 35

Correlation Study

Sedentary Group. The triangular intercorrelation matrix computed from nine measurements taken on 34 relatively sedentary males is presented in Figure X. The following observations were made on the basis of this matrix of simple correlation coefficients.

a) Per cent body fat correlated at the .01 level of significance with three other body measurements - relative body weight .890, total body weight .877, and fat-free body weight .797.

b) Resting heart rate measures did not correlate significantly, at the .01 level, with any of the body measurements.

c) Four variables correlated with treadmill performance time, at the .01 level of confidence:

per cent body fat	-.624
pre-test standing heart rate	-.617
relative body weight	-.494
total body weight	-.411

Since the physical or external work done in walking is directly proportional to the gross body weight, and the fat men are, as a rule, heavier, it was desirable to examine the relationship between performance time on the treadmill in minutes and the percentage of body fat, eliminating the effect of variablilty of body weight per se. The partial correlation analysis resulted in a value of r (partial) = -.603, which was significant at the .01 level of confidence (t = 4.638). Using

FIGURE X

Intercorrelation Matrix

Body Measurements, Heart Rate and Treadmill Performance
(N=34)

Variables	1 Height	2 Weight	3 Relative Weight	4 % Fat	5 Fat-Free Weight	6 Standing Heart Rate	7 Perf. Time	8 Recovery 3 Min.	9 Recovery 5 Min.
1. Height	___	.309	.033	-.002	.507	-.013	.200	-.090	-.110
2. Weight		___	.942	.877	.904	.141	-.411	-.003	.068
3. Relative Weight			___	.890	.797	.170	-.494	-.009	.076
4. % Body Fat				___	.601	.294	-.624	.111	.188
5. Fat-Free Weight					___	-.044	-.125	-.132	-.052
6. Standing Heart Rate						___	-.617	.339	.434
7. Performance Time							___	-.167	-.369
8. 3 Min. Recovery Heart Rate								___	.565
9. 5 Min. Recovery Heart Rate									___

$r \geq .403$; significant at .01 level
$r \geq .312$; significant at .05 level
$r\ x_7\ x_4.x_2 = -.603$; sig. at .01 level
$t = 4.638$

a variance interpretation, it was observed further that the percentage of the total association present resulting from the effects of body weight was approximately 8%. In other words, at equal body weight, the time taken for the heart rate to attain 180 beats / min. during walking, at progressively increasing workloads, was significantly and directly related to the percentage of body weight represented by fat.

Because of the difficulty of a direct "intuitive" interpretation of a coefficient of correlation, the r is perhaps the least useful method of expressing the association between variables (9:24), especially in situations where the number of independent variables is in excess of one (10). A more valid interpretation of relationships can be made by viewing the relative size of the contribution of each variable (five body measurements) to the variance in the criterion (treadmill performance time).

The relationship between treadmill performance and each of five body measurements, as determined by the step-wise procedure of multiple regression, is presented in Table XVII. The variables are ranked according to the order of their inclusion in the multiple regression equation. The second column represents the cumulative percentage of the total interpersonal variance in treadmill performance time accounted for by the inclusion of each successive variable into the multiple regression equation. For example, variable 1 accounted for 38.87 per cent of the total variance, variable 1 plus variable 2 accounted for 48.59 per cent ..., etc. The t scores, which tested the

significance of the beta coefficient for each regression, and the standard error of estimate, which indicates the deviation between the actual and predicted values of performance time for each regression equation, are also presented.

The variable showing the "best fit" with treadmill performance time was per cent body fat or "relative obesity" (11:86). This variable accounted for 38.87 per cent of the total inter-personal variance in the treadmill performance time of the group under study and yielded a beta coefficient with a t value of 4.92 which was significant at the .001 level of confidence for 32 degrees of freedom.

The final multiple regression equation, which was based on all five body measurements, accounted for a total of 52.21 per cent of the total interpersonal variance in treadmill performance time. Fifty decimal three one (50.31) per cent was contributed by measurements of relative obesity, fat-free body weight, and relative body weight, while the inclusion of gross body weight and height in the final equation added an additional 1.90 per cent to the total accountable variance.

Comparison of Sedentary and Trained Groups. The relationship between three measures of body mass and body composition and treadmill performance time was large enough to apparently account for slightly over 50 per cent of the total variability between individuals in the sedentary group studied. This raises the question of whether the differences in performance time observed with training, in the group of seven subjects formerly discussed at length, could be completely or

TABLE XVll

Relationship Between Treadmill Performance And Various Body Measurements (Multiple Regression Analysis) (N=34)

Measurement	% Age of Variance Accounted For By Regression	Standard Error of Estimate-Sy.x (mins.)	t Score	Rank
% Body Fat	38.87	2.928	4.92**	1.
Fat-Free Body Weight	48.59	2.722	2.65*	2.
Relative Body Weight	50.31	2.713	2.11*	3.
Height	52.03	2.703	1.41	4.
Total Body Weight	52.21	2.738	.292	5.

** - sig. at .01 level of significance; (d of. f. = N-n-1)
* - sig. at .05 level of significance

partially accounted for by changes in body mass and/or body composition.

In order to examine this question, the following general observations were made on pertinent data presented previously which graphically compared anthropometrical and physiological changes during training.

a) Over all three phases of the study, performance time and fat-free body weight were found to increase an average of 70.06 and 3.24 per cent of their respective initial values, while relative obesity and relative body weight declined 40.45 and 6.02 per cent respectively on the average. All of these

changes were significant (P>.01).

b) In all four subjects who initially contained more than 20 per cent of their weight as fat, measures of treadmill performance and relative obesity generally showed apparently similar changes, in opposite directions, during Phases 1 and 111. No distinct patterns of change were evident with the three leaner subjects, especially in the case of M.B. who gradually increased in both body measurements and treadmill performance throughout.

c) An analysis of final values (Test 4) reveals that the three most obese subjects were 30 to 59 per cent over-weight, 30 to 123 per cent over the mean value for relative obesity found for the sedentary sample and five to 14 per cent below the average treadmill performance time for the sedentary group.

A more precise estimation of the difference between the treadmill performance - body composition relationship in sedentary and trained individuals is found in Table XV111. This presentation comprised a comparison of the differences between predicted and actual (measured) treadmill performance times of the seven subjects, in both a sedentary state (Test 1) and at various stages of the training programme (Tests 2 and 4). The findings shown in this table were attempting then, to determine the precision with which one, two, or three body measurements could predict treadmill performance time under both sedentary and trained conditions.

The regression equations used for the purposes of prediction were chosen on the basis of the significance of their

beta coefficients (Table XVll) and are listed below. All equations were computed from data on the 34 sedentary males.

Equation	Standard Error of Estimate
A. Performance Time = 20.83-.386 (% Body Fat).	2.93
B. Performance Time = 10.10-.531 (% Fat)+.089 (Fat-Free Wt.)	2.72
C. Performance Time = 10.92-.367 (% Fat)+.127 (F.F.Wt.)-.079 (Rel.Wt.)	2.71

Under sedentary conditions (Test 1), the performance times of six of the seven subjects were over-estimated by at least one of the three regression equations based on body measurements. The errors, of actual from predicted times, were within the standard errors of estimate computed for each equation except in the case of the leanest subject initially, M.B., whose times were over-predicted by more than one standard error by all three equations. The mean errors found with subjects in a sedentary state are positive for all three equations indicating that performance time, on the average, was over-estimated. Equation A yielded the smallest mean error (+.88 mins.) of the three equations.

The results of Tests 2 and 4 reveal that performance times for all trained subjects were under-estimated by one or more of the equations based on body measurements. The errors in prediction were greater than one standard error of estimate in 5 of the 7 subjects and with at least one of the three equations. Only the performance times of one subject, G.H., were under-estimated to the point whereby the errors fell more than two

TABLE XVIII

The Prediction of Treadmill Performance From Body Measurements: Under Sedentary and "Trained" Conditions (N=7)

Subjects	Equation	Beginning Phase I (Test 1)			Terminal Phase I (Test 2)			Terminal Phase III (Test 4)		
		Predicted	Actual	Error	Predicted	Actual	Error	Predicted	Actual	Error
R.H. (35.0%)	A	7.32		+.32	10.56		-2.44	12.26		-2.24
	B	6.74	7.0	-.26	11.33	13.0	-1.67	13.96	14.5	-.54
	C	5.67		-1.33	10.18		-2.82*	12.70		-1.80
C.B. (33.9%)	A	7.74		+2.24	9.33		-4.17*	9.40		-4.10*
	B	7.77	5.5	+2.27	10.66	13.5	-2.84*	10.92	13.5	-2.58
	C	7.95		+2.45	10.87		-2.63	11.29		-2.21
M.G. (22.8%)	A	12.42		+1.42	13.30		-1.20	14.19		-.81
	B	12.94	11.0	+1.94	14.37	14.5	-.13	16.0	16.0	+1.00
	C	12.60		+1.60	14.03		-.47	15.79		+.79
G.H. (20.0%)	A	13.11		-1.89	14.50		-6.00*	15.46		-7.54*
	B	12.51	15.0	-2.49	14.52	20.5	-5.98*	15.90	23.0	-7.10*
	C	13.88		-1.12	15.42		-5.08*	16.65		-6.35*
L.Y. (13.2%)	A	15.73		+.23	18.40		-3.10*	19.67		-3.83*
	B	16.22	15.5	+.72	16.94	21.5	-4.56*	21.98	23.5	-1.52
	C	16.21		+.71	19.04		-2.46	20.73		-2.77*
J.D. (7.9%)	A	17.78		+.78	20.09		-.91	19.75		-1.75
	B	19.03	17.0	+2.03	22.43	21.0	+1.43	22.20	21.5	+.70
	C	18.75		+1.75	21.67		+.67	21.45		-.05
M.B. (3.0%)	A	19.63		+3.63*	19.63		-2.87	19.32		-4.68*
	B	19.36	16.0	+3.36*	19.86	22.5	-2.64	19.75	24.0	-4.25*
	C	19.23		+3.23*	19.59		-2.91*	19.57		-4.43*
Mean	A	13.31		+.88	15.11		-2.96*	15.72		-3.57*
	B	13.51	12.43	+1.08	15.73	18.07	-2.34	17.24	19.29	-2.05
	C	13.47		+1.04	15.83		-2.24	16.88		-2.41

* Error in prediction is ≥ 1 standard error of estimate

standard errors of estimate above the regression line.

The means computed at Tests 2 and 4 indicated that the average predicted times from all three equations were underestimating the actual or measured time. Only equation A, based on the relative obesity measurement, however, yielded errors greater than one standard error in its predictions. With the addition of the fat-free body weight and relative weight variables into the multiple regression equation, the error in prediction was reduced at Tests 3 and 4, the lowest error (-2.05 mins.) occurring with equation B.

Figure X1 illustrates the performance time - relative obesity relationship under sedentary (T1) and trained (T4) conditions. The regression line, and errors of estimate were computed from data on the 34 sedentary males (Equation A) and the Test 1 and Test 4 values for the seven subjects in the longitudinal study were plotted. The shift of plotted scores in a direction away from and above the regression line is evidenced in all seven subjects as they moved from a sedentary to a trained state.

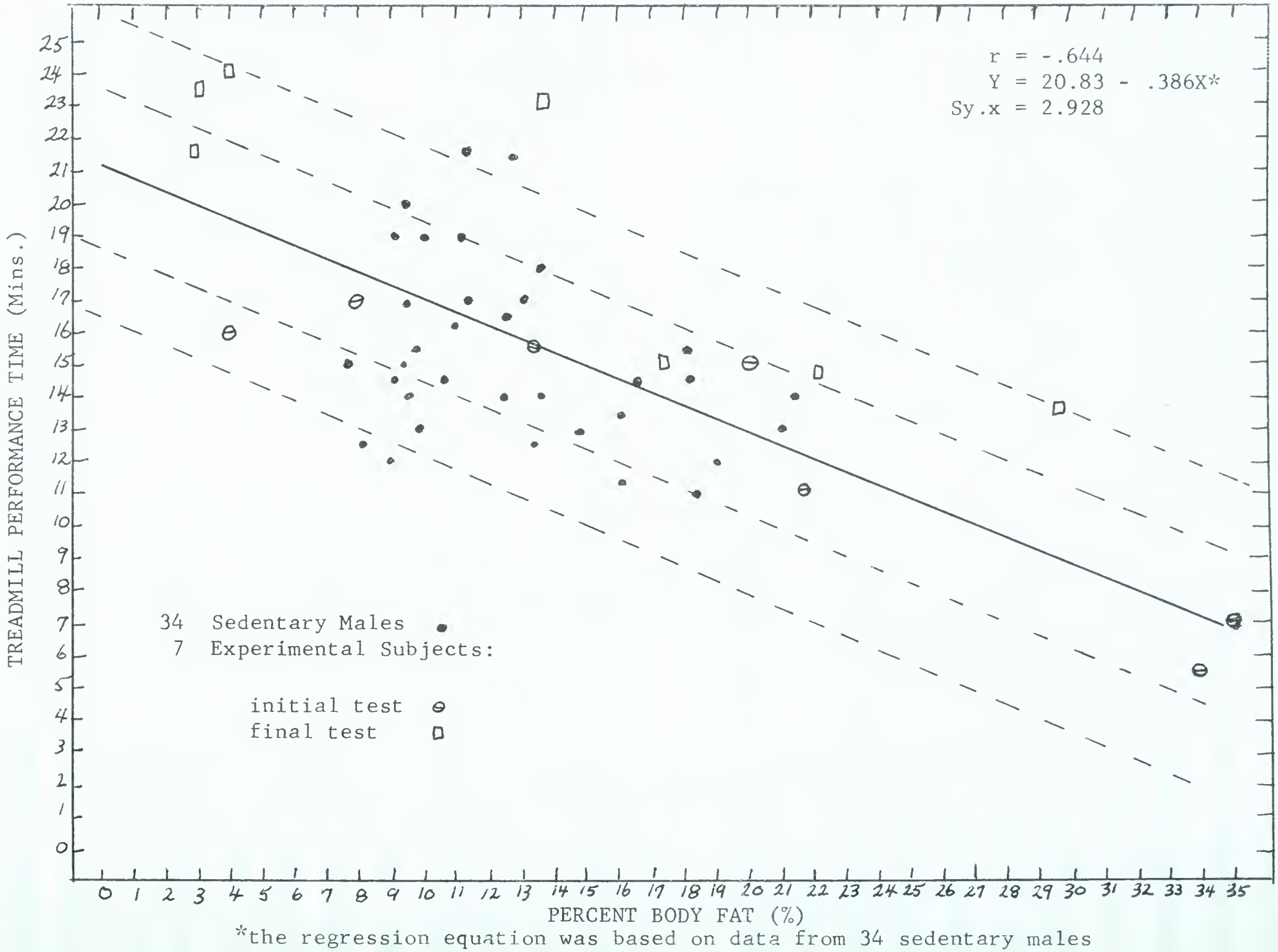
Discussion

Reliability and Validity of Measurements

All reliability coefficients for body measurements were highly significant and quite comparable to values reported by other authors who have investigated these particular techniques (12, 3, 11).

Body density was determined with the subject submersed following a maximal inspiration, and total lung capacity was

Figure X1
Relationship Between Per Cent Body Fat and Treadmill Performance Time
-Sedentary and Trained Conditions-



*the regression equation was based on data from 34 sedentary males

not measured at the time of weighing. While differences in residual volume measured during submersion and on land are reported to be "negligible" (13), the lung full of air is subject to greater relative pressures exerted by the water on the thoracic cavity and larger errors may result in the determination of density. These errors would effect the validity of cross sectional estimations of body density, but conditions for repeated, longitudinal measures on all subjects remained constant and therefore changes observed from test to test could not be similarly criticized. The value of 115 cc. assumed from the quantitative findings of Bedell, et al (14), for the volume of gas in the gastro-intestinal tract may be regarded as accurate, for densitometric purposes, in that all subjects were measured in a post-absorptive state.

The test-retest reliability coefficient for right hand grip strength, while achieving the one per cent level of significance, indicates an error of at least 35 per cent of the difference between trials and cannot be accepted for purposes of measurement. It was found, however, that changes in this measurement with training contributed less than one per cent, on the average, to the change in T.P.S. and its inclusion in a consideration of total changes in strength, therefore, would not create serios errors. It is important to note that all strength measures included in this study were designed to measure maximal volitional strength only and than no attempt was made to control completely the many psychological or motivational factors possibly involved in such a test.

The reliability coefficient of .964 found for treadmill performance time represented a mean difference between trials of .66 minutes. The reproducability of treadmill walking times in the present study, under conditions whereby brief practice trials preceded the initial test, was apparently higher than that found in similar investigations where practice trials were not employed. Reliability coefficients of .84 (8) and .88 (15) were reported under these last-mentioned conditions. Important factors, such as room temperature and humidity (17). were not regulated in any of these investigations and a true comparision of findings, therefore, is not possible.

The unacceptable consistency of measurement found for the recovery and pre-test standing heart rates is supported, indirectly, by the studies of Taylor (16) and Hodgson (8). These authors questioned the validity of resting heart rate determinations on the basis that changes in these measures, over a period of training, did not coincide with changes found in circulo-respiratory tests conducted under conditions of sub-maximal (8) and maximal (16) work loads. These findings are also in agreement with the poor relationships, found in the sedentary group (N = 34), between treadmill performance time and recovery heart rates.

An interpretation of changes in body density, in terms of body composition, from the formula of Brozek and Keys (1:268) is apparently limited in studies involving vigorous physical exercise. The validity of the formula is based on the assumption

(derived from nutritional studies) that all changes in body density, are a result of increases or decreases in obesity tissue. If an individual maintained this initial level of obesity tissue, which is primarily composed of fat, and increased his muscular weight, his body density would increase. The formula would fallaciously interpret this density increase as a reduction in obesity tissue. This concept is in agreement with the findings of Buskirk and Taylor (51) who reported body densities in excess of 1.1 with athletes. The formula of Brozek and Keys would interpret such density values to mean that the individual possessed no body fat.

Anthropometrical Changes. All subjects, who were initially overweight, experienced losses in body weight while undergoing a daily program of vigorous exercise and sports. The weight loss was composed primarily of a reduction in subcutaneous and total body fat and, to a lesser extent, an increase in fat-free body weight - presumably mainly muscle. During a subsequent brief five week period in which activity participation decreased, or became almost non-existent, the above mentioned variables continued to change in the same direction at a substantially reduced rate, were resistant to change or reversed the pattern of change observed during training.

Assuming that the loss of fat is achieved solely through the creation of a negative caloric balance and that energy expenditure is proportional to body mass (17, 18, 19), it would be expected that the degree of fat loss would be somewhat proportional to the degree of obesity or overweight. The most

obese subject, initially (R.H.), reduced his total weight and fat to a greater extent than any member of the group. However, in the remainder of the initially overweight subjects, especially in the cases of C.B. and M.G., the extent or rate of fat loss was not dependent upon the initial degree of obesity. Passmore, et al (20), and Sonka, et al (21), reported similar findings in studying obese males undergoing combined treatments of caloric restriction and exercise.

Several explanations of this occurrence appear to be warranted. Although all subjects were exposed to similar programs, in terms of time, each subject was encouraged to work only at or towards his own individual maximum. Considering also the extremely low skill levels of the three most obese subjects upon entering the program and the evident differences in their rate of motor learning, it was not unreasonable to expect wide differences in energy expenditure. Hanson, et al (22), have recently shown that spontaneous physical activity in rats is greater after periods of forced exercise than following similar time periods of normal activity; and that the intensity of spontaneous activity in the exercised group was closely related to the degree of weight loss attained. Although such findings have obvious limited applicability to humans, it might be expected that attainment of immediate successes, in regard to fat loss, would promote greater spontaneous activity, especially in individuals who had previously participated in virtually no vigorous exercise of any description.

Changes observed in gross body weight did not provide a

true indication of changes, in either direction, in body composition. Furthermore, there was no evidence to indicate that weight changes during training could be attributed to increases or decreases in "obesity tissue".. the composition of weight changes found under conditions of excessive caloric intake (increase) or caloric restriction (decrease) (1, 23, 24). With reductions in weight, fat loss, in both obese and non-obese subjects, was accompanied by increases in fat-free body weight. This observation was confirmed even in the case of subject R.H. who lost an average of slightly over 3.25 lbs. of weight per week over the first eight weeks of exercise and almost 15 per cent of his initial body weight during the entire eighteen weeks. Similarily, increases in gross weight, observed during training with some of the subjects, were accounted for entirely by a gain in non-fatty tissue, while total and skinfold body fat continued to decrease.

The methods of measurement do not provide a detailed partitioning of the fat-free body mass. However, an analysis of data obtained from measurements of limb circumferences, corrected for their covering of subcutaneous fat, and in view of the progressive nature of the training program under study (25, 26) it would appear that the greater majority of the increases observed in the fat-free body component may be attributed to an increase in skeletal muscle. The anthropometric photographs, in addition, indicate that muscular mass was increased with training at body sites other than those actually measured.

It has been found, in related studies (20, 27) as well as the present one that obese individuals have heavier fat-free body weights despite the fact that a greater percentage of their gross weight is composed of fat. It was also presently observed, in a comparison between subjects as well as within the same subjects, that the weight of the fat-free body tended to increase the most during training periods when fat reduction was least. Passmore concluded on the basis of his finding with sedentary obese subjects (20:117): "In some obese persons, especially active ones, there is muscular hypertrophy arising out of the need to move excess weight." It would follow then that with formerly sedentary obese persons engaged in activities which constantly required moving and lifting the body from place to place, the degree of hypertrophy in the muscles engaged in the work would increase generally in proportion to the amount of excess fat or weight being lifted. Increases in muscular mass with those subjects who were carrying an excessive burden of fat amounting to less than five per cent of their gross weight, however, could not be attributed solely to lifting and moving the body mass. It is conceivable that the overload required for hypertrophy with these individuals was derived, to a greater extent, from the progressive resistance exercise portion of the program involving weight training and isometric contractions.

In the five weeks of reduced or normal activity (Phase 2), measurements of fat-corrected limb circumference did not indicate that any atrophy or decrease in muscular mass was

taking place. These findings are consistent with those of Yuhasz (3) who reported that newly gained muscle mass in athletes failed to decrease until the six month of detraining.

Subject M.B., at 24 years of age, had never previously attained a gross body weight greater than 128 lbs. Although this subject contained only three per cent of his weight as body fat initially, the weight of his fat-free body mass was 24 lbs. less than any of the remainder of the group and 33 lbs. below the lowest of the mean values reported for college men (2). These initial values are supported in part by the quantitative studies of Passmore, et al (28), and McCance and Widdowson (29) who reported that men with relative body weights ranging from 70 to 77 per cent contained "normal" amounts of fat, (29:128) "... the real abnormality in these men being that they contained two little cell mass." Grafe's (30:20) early theory of a "luxus consumptions mechanism" which burns off any excess food intake in thin men was not supported by Passmore, et al (28, 31), who concluded, from faecal analysis and energy expenditure determinations, that while over 90 per cent of excess food was absorbed (30:25), "... there is no shred of evidence to suggest that the thinness of these young men is due to any inherent ability to oxidize surplus food."

During training, over 95 per cent of the gain in weight observed in M.B. was composed of non-fatty tissue and his initial determinations of muscle mass increased a total of 9.73 per cent. These results are in apparent opposition to findings from nutritional investigations (28, 29, 31), where a two-fold increase

in the caloric intake of thin men produced a "somewhat depressed" gain in body weight, of which over 85 per cent was accounted for by an increase in body fat.

Physiological Changes. Increases in total proportional strength and strength per pound of weight and fat-free weight were observed during periods of training. The degree of improvement in strength did not appear to be directly dependent upon the gross body weight or the weight of the fat-free body in that:

a) Initial and final values of T.P.S. were lower with the more obese subjects and

b) Increases in strength per lb. of fat-free weight indicated that strength was increasing at a rate much faster than that component of the body which was directly involved in the strength measurement. The findings are in agreement with the low correlations between strength and lean body mass and body fat reported by Rasch (32:375). This author also pointed out, on the basis of his correlational analysis: "The fact that the heavier non-athletes are weaker per pound of body weight is not explained by the presence of a greater amount of fat in their body composition."

It is apparent that the greater majority of differences in total strength within the same individual, and possibly between individuals, may be attributed to the circulatory (32) or neuro-muscular (34) changes associated with progressive resistance exercise. Decreases in muscular strength, found with detraining,

were similarly not apparently associated with concomittant changes in body composition. Reductions in strength during Phase II, rather, were found to compare closely to the degree of increase found in the preceding period of training. This pattern of strength change is consistent with the quantitative determinations reported by Muller (35).

The findings in the present study are based on measurements of body compartments and total proportional strength and can not be extended to comparisons of tissue and strength changes in individual muscle groups. The results, then, are not necessarily in contradiction to the high relationships found between strengths and limb circumferences, as indicated in a study by Tanner (36).

During training, subjects experienced highly significant increases in B.M.R. in terms of cc./kg. gross body weight. Similar increases in this ratio have also been reported by authors who have studied athletes over the course of training (37, 38). These changes in B.M.R. were attributed entirely to "... an increase in the active protoplasmic tissue (37:130)." It can not be concluded, however, that B.M.R. in cc./kg. of weight was significantly increased in all body tissues. Kleiber (39) has shown, in rats during semi-starvation, that separate body tissues respond very independently to changes in the total B.M.R. Similarly, it would also appear to be erroneous to attribute the entire increase in B.M.R., in the present study, solely to the addition of muscular mass or other anthropometrical

changes. During Phase 11, average reductions in oxygen intake, per kg. of weight and in cc./min., were observed without simultaneous reductions in fat, muscle mass, or fat-free body weight. While these metabolic changes were not statistically significant, they suggested that at least a portion of the increase in B.M.R. observed during training was influenced by factors which were changing independently of the anatomical measures considered. Previous investigations concerned with the effects of aging (40) and semi-starvation (41) reveal that the adaptation of the B.M.R. to these changing conditions produced a decrease which was not wholly accounted for by a reduction in the mass of tissue lost. A more precise understanding of factors other than anatomical variables, which influence a change in the total B.M.R. would require an examination of intermediary metabolic mechanisms.

It was also found that six of the seven subjects reduced their oxygen intakes in cc./kg. fat-free weight over the initial eight weeks of exercise. While changes in this ratio were not as great as those found in using the gross weight "standard", they were sufficient on the average to attain significance at the .05 level of confidence. The use of the fat-free body weight as a basal metabolic reference standard has been supported on the basis of its consistency of expression between the sexes (6), and among both normal individuals (2, 42). as well as those differing in their degree of obesity (2, 1, 43). The validity of this ratio is dependent upon the principle that the body can be

partitioned into metabolically active (fat-free) and relatively inactive (fat) components. A decrease in cc./kg. fat-free mass, then, would apparently indicate a "... decrease in the energy expenditure of the cells themselves." (1:312)

When muscular mass, which has been shown to account for 25 to 30 per cent of the basal metabolic expenditure (44), is added to the body, a decline in cellular energy expenditure would not be expected. Fat, however, was also being reduced significantly in these subjects, and it is presently suggested that any decline in basal oxygen consumption, during the training periods, may conceivably be principally attributed to this loss of fat. This suggestion is based on the following findings, from previous as well as the present study:

a) Fat has been shown to have a significant, positive statistical relationship with basal oxygen consumption (2, 45, 46), and measures of a combination of muscle and fat correlated higher with basal oxygen intake than did muscle mass alone (2, 43).

b) The finding (47) that fat accounted for only a "... fairly small fraction" of the basal oxygen consumption was based on data from "normal" and not obese or "overweight" subjects.

c) Adipose tissue is constantly active, metabolically, in conducting such processes as glucose utilization, fat synthesis from carbohydrates, fat deposition and respiratory activity (48).

d) In the present study, basal oxygen consumption increased when the proportion of fat lost to fat-free weight gained,

was reduced, as in Phase lll or in the case of M.B. where fat reduction did not accompany a gain in fat-free weight.

The mean increase in treadmill performance time, found with training, was more significant statistically than any of the other physiological parameters measured (t = 7.966). Obese and non-obese subjects did not differ in their degree of increase, but the former group remained substantially below the latter under both trained and untrained conditions. The exercise program appeared to have achieved a substantial degree of success, in terms of cardio-vascular conditioning for sub-maximal work, in that "normal" subjects raised their performance times to the level of and even above those reported for inter-collegiate athletes (49), while the obese subjects attained, or were within one minute of, normal values.

During the brief period of reduced or normal activity (Phase ll), there was no evidence to indicate that any of the improvements experienced in treadmill performance during the initial eight weeks of training had not been retained. Micheal, et al (50), also found that treadmill performance time and oxygen uptake during sub-maximal work were maintained at high levels, throughout 30 weeks of detraining, with former olympic and inter-collegiate athletes. These findings can not be extended, however, to all types of exercise programs. Alexander, et al (49), found that gains in treadmill performance time observed with subjects undergoing a brief, intensive type of conditioning regimen were slightly reduced during the initial two weeks of detraining. It is important to consider that the

rate of increase observed with the present subjects, who were training vigorously for almost one hour daily, was well above that found for participants in shorter, but probably more intensive, programs (49, 8, 15). It is conceivable, then, that the type of training program as well as the amount and/or percentage of increase in performance might have a direct bearing on the degree of retainment.

Treadmill Performance - Body Composition and Body Mass Relationships

Sedentary Conditions. A combination of five measures of body mass and body composition were found to account for 52.21 per cent of the total interpersonal variance in the treadmill performance times of the sedentary group studied. Relative obesity, or that percentage of the gross body weight which was composed of fat, accounted for 38.87 per cent of this total variance and showed a highly significant negative correlation with treadmill performance time when the effect of gross body weight was partialled out ($t=4.638$). These latter two relationships were also found to be significant, but lower, in a study by Buskirk and Taylor (11) when heart rate measured during treadmill walking in the "steady state" was used as the physiological criterion.

The present findings can not be extended, however, to include maximal performance tests (51, 52) or determinations of basal cardiac function (53). They do not imply, furthermore, a contradiction of those findings (18) which revealed that obesity

or excess fat, per se, was not an important factor in the etiology of cardio-vascular disease. Maximal oxygen intake (51) and basal cardiac output (53) were found to correlate significantly with the fat-free body weight but not with body fat, while total body weight accounted for less than 12 per cent of the total variance in maximal treadmill running time (52). While this last mentioned study did not include body composition variables in the regression analysis, and the state of training of the subjects is not known, it is important to consider the author's findings that over 60 per cent of the total variance in running time was accounted for by circulo-respiratory measures of oxygen intake and pulse rate.

In view of the above findings and the recent results of a similar study involving a factor analysis of cardio-vascular condition (55), a clarification of present findings is necessitated. The significant negative correlation between relative obesity and treadmill performance time is consistent with, but does not necessarily prove a causal relationship between the percentage of gross weight which is composed of fat and the performance time on the treadmill. Furthermore, it is not evidence that cardio-vascular parameters are relatively un-important as limiting factors, but rather that the two variables are intimately related in the normal individual and raises the question of whether one (the various cardio-vascular paramenters) is not controlled or influenced through some intermediate mechanism by the other (relative obesity). This interpretation would also apply to the significant relationship found between

the combined anthropometrical measures and treadmill performance time.

This "intermediate mechanism" is not clearly defined, but some degree of speculation, on the basis of related study, appears to be warranted. Firstly, the obese man is under a substantial handicap in physical performance requiring exhausting work because of the load of fat, which does not contribute to his performance, and which he must carry with him. Buskirk and Taylor (51:78) concluded from their findings that, while obesity and maximal oxygen comsumption were not correlated, the excessive load of fat "... makes the accomplishment of a specific work task more difficult." Conversely, the addition of muscle mass or fat-free body weight would apparently be a contributing factor to improved performance. Miller and Blyth (43:140) have similarly shown that increasing amounts of body fat are lifted during exercise as an excessive, inert weight and that the work capacity of an obese person is definitely limited, as the oxygen requirement per unit of lean body mass rises without a corresponding increase in the capacity for oxygen uptake.

Much evidence (55, 56, 57) has been shown recently in support of the concept that the dimensions of the peripheral vascular bed have a profound influence on the quantity of blood returned to the heart and the cardiac output. Taylor concluded (55:146): "In submaximal states, there is an elegant balance between cardiac output, blood pressure, the size of the vessels in the muscles, and the venous return." In turn, increasing

amounts of body fat, according to the findings of Rushmer (58), would appear to have a definite effect on this important determinant of cardiac function. This investigator concluded (58:233): "Obesity is frequently accompanied by atherosclerosis and mild or moderate degrees of hypertension with some potential increase in the volume load on the heart due to the proliferation of capillary beds into newly formed adipose tissue."

Per cent body fat was superior in its relationship with treadmill performance to both relative and gross body weights. This order of relationship is consistent with the findings of Buskirk and Taylor (11). While significant correlations were found presently between per cent body fat and relative (.890) and gross (.877) body weights, the relationships shown above, in combination with the previously discussed analysis of weight changes during training, definitely indicate that gross body weight and relative body weight, to a lesser extent, do not provide accurate indicies for the evaluation of obesity.

Sedentary and "Trained" Conditions. The regression equations based on data from 34 sedentary males were accurate within two standard errors of estimate in predicting the mean treadmill performance times of seven subjects, in both trained and untrained states. This accuracy of estimation under varying conditions would apparently indicate that the significant anthropometrical-physiological relationships found in sedentary subjects were maintained in individuals who had undergone an extensive program of training. There is some evidence to the

contrary, however, which illustrates that as training progressed, body fat and relative body weight and, to a lesser extent, the weight of the fat-free body, were becoming less important determinants of sub-maximal cardio-vascular performance than they had been under sedentary conditions.

This trend is evidenced in the increase in error with all equations, as training progressed and is most noticeable in those subjects (N=3) who had attained a very high level of performance. Furthermore, the increase in error was in the direction of underestimation which would indicate that active subjects were walking longer than would be anticipated, under sedentary conditions, for the degree of relative obesity, relative weight, of fat-free body weight which they possessed. Percentage increases in treadmill performance time were substantially superior to changes in any aspect of body mass or composition and it was observed that subjects who were still very much obese, in regard to fat content, were performing at or near the level of sub-maximal work capacity found for normal college men.

Previous study (51, 59) has shown that highly trained athletes perform, in terms of maximal oxygen intake at significantly higher levels than their physically inactive contemporaries and yet, quantitatively, are similar in both body mass and body composition. The differences between the trained and untrained would, in part at least, be due to an improved cardio-vascular performance, which may be related to the fact that the well trained muscle has a larger vascularization than the untrained

muscle (55:148). Similarly, studies involving middle aged and older men (11, 60) reported insignificant relationships between relative obesity and the heart rate response during exercise. This loss of correlation with increasing age was explained by Buskirk (11) to be due to the gain in importance of myocardinal degeneration as a determinant of the heart rate response to exercise.

Increases in treadmill performance time in the present study were accompanied by marked changes in body composition and it is not possible, at this time, to evaluate the extent to which either cardio-vascular or anthropometrical variables have contributed to this improvement. Any attempt to separate the influence of these two sets of variables requires the assumption that they are changing independently of one another. In light of previous discussion, it is apparent that a reduction in excess body fat would have a beneficial effect on peripheral circulation along with a definite reduction in the oxygen required for a specific work task. There is an indication, from the decline in relationships observed with training, however, that improvement in certain cardio-vascular variables, which have been shown to be important determinants of sub-maximal work performance (52, 54, 55), was greater than would be found or expected solely from a reduction in relative obesity or relative weight or an increase in fat-free body weight.

A more precise evaluation of the contribution to cardio-vascular performance of <u>either</u> training (or some other form of treatment) <u>or</u> anatomical changes would require the somewhat

imposing task of controlling one of these combinations of variables. It is interesting to note the findings of Kotilainen, et al (61), in this regard. Initially, "overweight" men who were subjected to a controlled diet of 800 cal/day over a period of three months and who lost a significant (13.2 kgs.) amount of weight on the average demonstrated a reduction in both the resting and post-exercise pulse rates. In those overweight subjects who, for some unexplained reason did not lose weight on this dietary regimen, no changes in the physiological parameters were found.

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CHAPTER V

SUMMARY AND CONCLUSIONS

Summary. Anatomical and physiological changes occur in individuals participating in vigorous physical activity. It has been the purpose of this study to assess certain aspects of these changes in a small group of obese and non-obese young men, and particularly to examine the relationships between changes in body composition and changes in selected measures of body functions.

Seven men differing markedly in body fat content were tested at the beginning and end of consecutive period of: daily training (8 weeks), voluntary training (5 weeks) and daily training (5 weeks). Body composition was assessed by means of water immersion densitometry, skinfold fat measures, and both gross and fat-corrected body dimensions. The physiological variables under study were basal metabolic rate, muscular strength and the Balke treadmill test of sub-maximal work capacity. Caloric consumption, over the entire 18 weeks and physical activity, during the period of voluntary activity, were recorded daily. Mean changes between tests in all measures for the six initially overweight subjects were tested for significance at the .05 and .01 levels of confidence. Changes in body measurements were plotted against physiological changes and presented graphically for each subject.

Thirty-four healthy but relatively inactive young men were tested to determine the relationship between treadmill

performance time, - and body mass and body composition. The data were analyzed by multiple regression procedures and predictive equations were computed. The relationships obtained were then tested under both sedentary and trained conditions by assessing the ability of the equations (based on data from the sedentary males) to predict the performance times of the seven subjects at various stages of their training.

Conclusions. Within the limitations of measurement reliability, the following changes and relationships were observed with men undergoing a program of vigorous physical exercise.

1. Men who were initially overweight experienced losses in gross body weight which ranged from 1.6 per cent to 14.5 per cent of their initial values (mean= -5.5 per cent). All weight losses were accompanied by decreases in total body and skinfold fat and increases in fat-free body weight and muscle mass.

2. The degree of fat loss was not dependent upon the initial level of obesity. Fat-free body weight was increased most in those subjects who experienced the smallest reductions in body fat.

3. One very thin subject increased his gross body weight a total of 10.5 lbs. or 8.3 per cent of his initial weight. Over 95 per cent of the weight gain was composed of an increase in fat-free body weight and muscular mass. Weight changes in either direction, with both obese and non-obese

subjects undergoing daily training, could not be attributed to increase or decreases in "obesity tissue" - the composition of weight changes found under conditions of excessive caloric intake (increase) or caloric restriction (decrease).

4. During a five week control period in which activity participation decreased or became almost non-existent, measurements of body composition continued to change at a substantially reduced rate, were resistant to change, or reversed the pattern of change observed during training. Measures of muscle mass did not change over this period.

5. Total Proportional Strength increased with training and generally decreased, in proportion to the degree of increase, during five weeks of detraining. Neither initial values nor increases in T.P.S. were directly dependent upon either gross or fat-free body weight.

6. a) Basal oxygen consumption per unit of body weight increased during training. The entire increase in B.M.R. could not be accounted for solely by changes in body mass or body composition, i.e. muscle mass.

b) During the first eight weeks of exercise, basal oxygen intake per unit of fat-free body weight declined. This reduction in oxygen intake was attributed to a marked decrease in body fat.

7. The most significant increases in any physiological measure were observed with treadmill performance time (t=7.966). Obese subjects improved their performance times (4 to 8 minutes) to the level of or just below the mean reported for normal

college men while the non-obese subjects had similar increases (4.5 to 8 minutes) which produced final values similar to those reported for athletes in training. Performance levels attained during training were retained over the five week period of reduced activity.

8. Anthropometrical measurements of relative obesity (38.87%), fat-free body weight (9.72%), relative body weight (1.72%), height (1.72%) and weight (.18%) accounted for 52.21 per cent of the total inter-personal variance in the treadmill performance times of 34 relatively sedentary young men. Each of the first three variables contributed significantly to the total variance. At equal body weight, the time taken for the heart rate to attain 180 beats/min. during walking at progressively increasing work loads, was significantly and directly related to that per centage of the body composed of fat (partial r = -.603). The importance of body composition as a possible determinant of cardio-vascular function during sub-maximal work was discussed.

9. The regression equations, based on body measurements and treadmill performance data from the sedentary group, overestimated the performance times of seven subjects prior to training and underestimated their times at each of two stages during training. Errors in prediction were greater under "trained" than under sedentary conditions but were still within two standard errors of estimate in six of the seven subjects. Training or daily physical exercise was contributing to the improvements in sub-maximal cardio-vascular performance time

in both obese and non-obese subjects, somewhat independently of reductions in body fat and relative body weight and increases in fat-free body weight. This contribution was greatest in those subjects who had attained the highest levels of performance.

The present findings are in agreement with previous clinical and laboratory observations which have associated obesity with an accumulation of excess body fat as well as sub-normal levels of cardio-vascular performance, muscular strength and basal metabolism. It was further evidenced that a progressive program of vigorous, physical exercise contributed to the therapy of obesity by:

a) specifically or directly changing each of the above parameters, and

b) rendering changes in certain aspects of body composition which in turn contributed to improvements in the selected physiological variables.

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APPENDIX

APPENDIX A

Statistical Formulae

1. a) Pearson Product - Moment Coefficient of Correlation

$$r_{xy} = \frac{N(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2}}$$

b) Partial Correlation Coefficient

$$r_{x_1 x_2 \cdot x_3} = \frac{r_{x_1 x_2} - (r_{x_1 x_3})(r_{x_2 x_3})}{\sqrt{[1 - (r_{x_1 x_3})^2][(1 - (r_{x_2 x_3})^2]}}$$

$$t = \frac{r_{x_1 x_2 \cdot x_3}}{\sqrt{\frac{1 - (r_{x_1 x_2 \cdot x_3})^2}{N-3}}} \qquad \text{(deg. of freedom = N-3)}$$

2. Significance between Means - Paired Samples

a) $$t = (\bar{d} - o) \times \frac{\sqrt{N-1}}{S.D.(d)}$$

b) $$S.D. = \sqrt{\frac{\Sigma x^2 - \left(\frac{\Sigma x}{N}\right)^2}{N-1}}$$

3. Multiple Regression - Step-Wise Procedure

a) Regression Equation

Y = a + bX (for 1 variable (x) and dependent variable (Y))

b) Standard Error of Estimate for Regression

$$S_{y.x} = \sqrt{\frac{\Sigma (Y - \hat{Y})^2}{N}}$$

c) F Ratio

F = Mean Sg. Residual/Mean Sg. Error

degrees of freedom for F = n/N-n-1

d) t Ratio

$$t = \frac{\text{Beta Wt.}}{\sqrt{\text{St. Error Beta Wt.}}} \qquad \text{degrees of freedom = N-n-1}$$

APPENDIX B
MEASUREMENT OF BODY COMPARTMENTS

Time_____ Name_____ Age_____

Temp._____°C Date_____ Study_____

Water Temp. _____°C

B.P. (mm. Hg) _____

Water Density_____

Densitometric Determination

1. Weight in Air (x)_____lbs.
2. Apparent Weight in Water (full inspiration) (x)_____lbs.
   (full expiration) (x)_____lbs.
3. Weight of Apparatus (x)_____lbs.
4. Submerged Weight = =====
5. Total Gas Volume (T.L.C.) ____ + (V.G.I.)____ = _____ cu. in.
   _____cu. in. x .0362 = _____ lbs.
6. True Weight in Water (4)_____ + (5.)____ = _____lbs.
7. Body Volume (1.)_____ - (6.)____ = _____lbs.
8. Body Density (1)_____ X (D. Water)____ = =====
   (7)

TOTAL BODY FAT

a) D = _____(table)

Total Fat = _____ or _____%

b) Fat Weight=(1.)_____X

(a)_____ =_____lbs.

c) Fat Free Weight =(1)_____

- (b)_____ = ____lbs.

Verification of LUNG VOLUMES (B.T.P.S.)

Land Vital Capacity = _____l

Residual Volume _____

Total Lung Cap. =====

Water (x)

V.C. (spirometer)

_____l; X_____ = _____l(BTPS)

V.C. (weight diff.)

=_____lbs. X 0.0362 = _____l

APPENDIX C

Measurement of Functional Residual Volume. (closed circuit Helium dilution method):

The test began with the initial concentrations of helium in the lungs equal to zero and in the spirometer being precisely 10 per cent (a known value of helium being added to the spirometer before starting the test). The subject then rebreathed from the spirometer until mixing was complete, i.e., the concentration of helium was the same in both lungs and the spirometer. A Godart analyzer was used for measurements of helium concentration.

The initial volume of gas in the lungs was then computed on the principle that the number of molecules of helium is the same in the lung-spirometer system at the end of the test as at the beginning. Thus:

Amount of He in lungs + amount of He in spirometer = total amount of He.

Amount of He = volume of gas (V) X fractional concentration of helium(F).

Therefore:

$$V_L F_L + V_S F_S = (V_L - V_S) F_L$$

(initial Lung) (initial spirometer) (end lung + spirometer)

If the volume of the lungs is unknown and the volume of the spirometer is 2,000 ml., and the initial and final concentrations in the bellows are 10 per cent and 5 per cent respectively:

$$0 + (2000 \times 0.10) = (V_L + 2000)\ 0.05$$

$$200 - 100 = 0.05\ V$$

$$V_L = 2000\ ml.$$

Measurement of Static Strength:

1. Back Lift - The subject stood erect with feet flat on the platform, hands on the front of the thighs, and fingers extended downwards. The dynamometer chain was hooked so that the bar level was immediately below the finger tips and the subject firmly grasped the hands at the ends of the bar with one palm forward and one palm backward. The subject was then in a position to lift, with the back bent slightly at the hips but with legs straight and no bend at the knees. The subject lifted steadily with the administrator firmly grasping his hands throughout the lift.

2. Leg Lift (with belt) - The subject took a position on the platform with the feet flat, back straight, head up, and the knees flexed at 110 - 115 degrees for each trial. The bar was held with both hands together in the centre, palms down and so that it rested at the junction of the thighs and the trunk. The loop end of the belt was slipped over one end of the handle; the free end looped around the other end of the bar and tucked under so that it rested next to the body. The administrator held the bar firmly against the subject's body during the lift. A lift was considered to be "maximum" only when the subject's legs were straight at the end of the lifting effort.

3. Grip Strength (right and left hands). The

manuometer was placed, face down, in the subject's palm in such a manner that the convex edge of the manuometer was between the first and second joints of the fingers and the rounded edge was against the base of the hand. The thumb was either touching or overlapping the first finger. The manuometer was then "gripped" with the subject's elbow slightly bent and the hand moved in a sweeping arc downward. The hand or elbow was not allowed to touch the body, or any object, while the test was being administered. Left and right hands were tested alternately with a brief rest between each trial.

SAMPLE CALCULATIONS

1. Body Density:

Subject's land weight	= 174.5 lbs.
Apparent weight in water at full inspiration	= 07.8 lbs.
Weight of abdominal belt and apparatus in water	= 12.7 lbs.
Subject's weight in water with full inspiration	= -4.9 lbs.
Total Lung Capacity (B.T.P.S.) (Vital Capacity + Residual Volume)	= 437.37 cu. in.
Volume of air in gastrointestinal tract V.G.I. (Average Volume at B.T.P.S.)	= 6.71 cu. in.
Total volume of air (T.L.C.+V.G.I.)	= 444.08 cu. in.
Weight of total volume of air = 444.08 x 0.0362	= 16.076 lbs.
True Weight in Water = -4.90+16.076	= 11.176 lbs.

Body Volume = Weight in air - true wt. in water
= 174.50 - 11.176
= 163.324

Body Density = $\frac{\text{Weight in air}}{\text{Body volume}}$ X Density of water

$$= \frac{174.50}{163.324} \times 0.997$$

$$= 1.0652$$

2. Body Components:

Substituting in from the above example:

$$\text{Total Fat} = \frac{4.201}{1.06521} \times .3812$$

$$= .131$$

Expressed as a percentage = 13.1% total fat.

Fat weight of the body = 174.50 x .131

= 22.86 lbs. (10.36 kgs.)

Fat Free Weight of the Body = 174.50 - 22.86

= 151.64 lbs. (68.73 kgs.)

3. Residual Volume:

Amount of He. in lungs = amount of He. in bellows - total amount of He.

Amount of He. = volume of gas (V) X fractional concentration of helium (F).

Therefore:

$$(V_2F_2) + (V_BF_B) = (V_2 - V_B)F$$

(initial lung) + (initial bellows) = (end lung - bellows)

If the volume of the lungs is unknown and the volume of the bellows is 2,000 ml., and the initial and final concentrations in the bellows are 10 per cent and 5 per cent respectively:

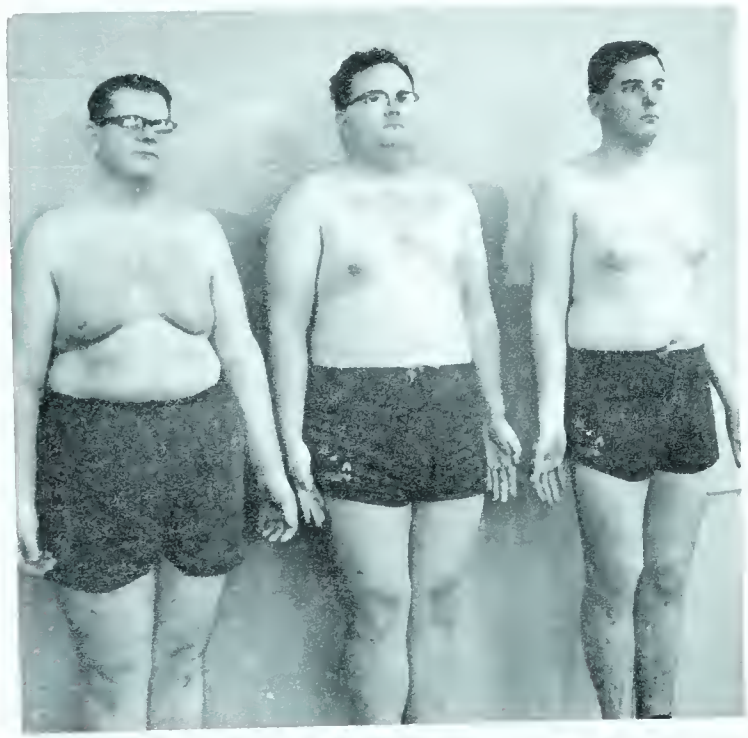
$$0 + (2000 \times 0.10) = (V_2 + 2000)\ 0.05$$

$$200 - 100 = 0.05\ V_2$$

$$V_2 = 2000 \text{ ml.}$$

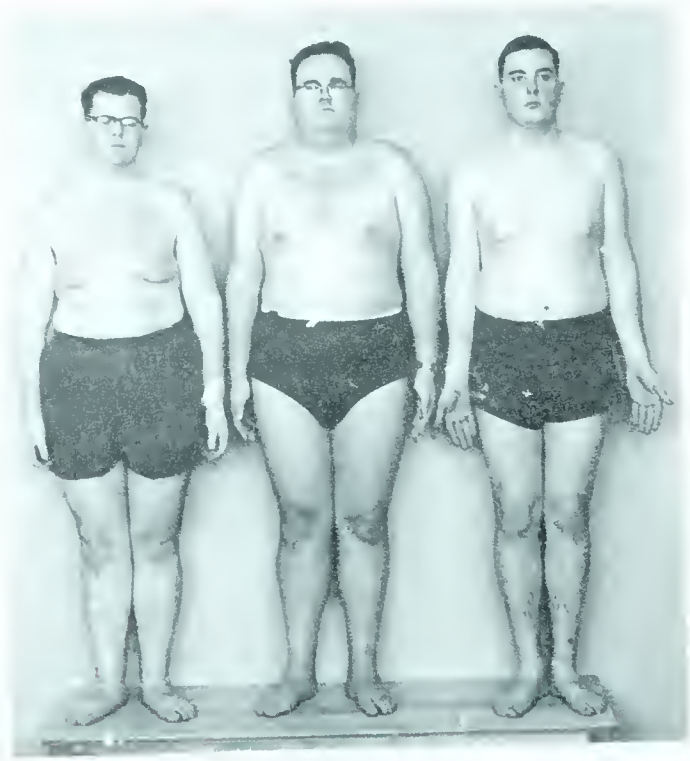
R.V. = functional residual capacity - expiratory volume with the subject breathing at the "more constant" resting expiratory level.

Front View of Subjects R.H., C.B. and M.G. At Various Stages of Treatment



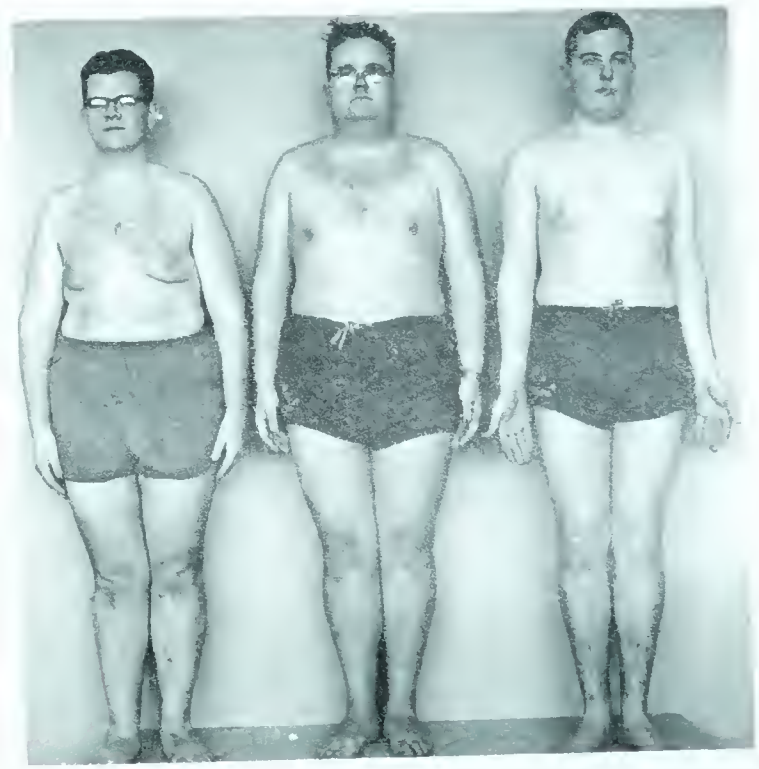
R.H. C.B. M.G.

Initial Day of Phase I



R.H. C.B. M.G.

Final Day of Phase I



R.H. C.B. M.G.

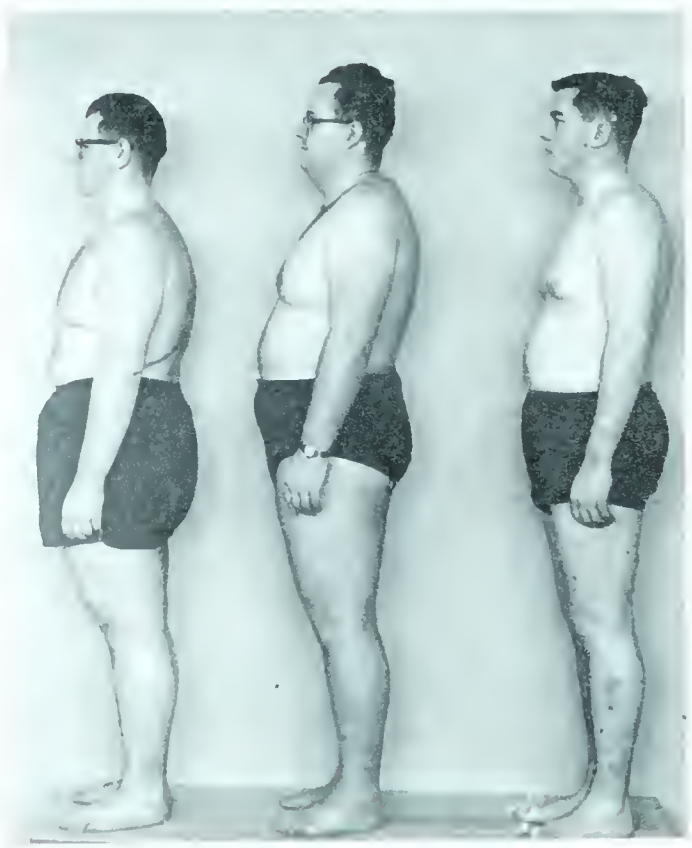
Final Day of Phase III

Side View of Subjects R.H., C.B. and M.G. At Various Stages of Treatment



R.H. C.B. M.G.

Initial Day of Phase I



R.H. C.B. M.G.

Final Day of Phase I



R.H. C.B. M.G.

Final Day of Phase III

Front View of Subjects R.H., C.B. and M.G. At Various Stages of Treatment



R.H. C.B. M.G.

Initial Day of Phase I



R.H. C.B. M.G.

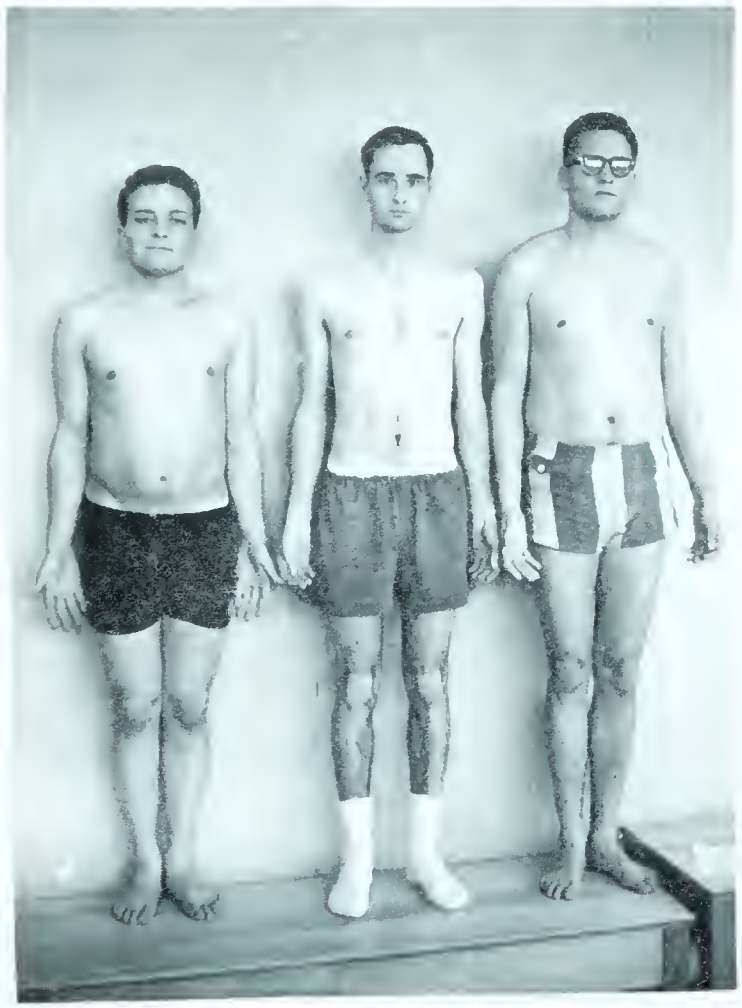
Final Day of Phase I



R.H. C.B. M.G.

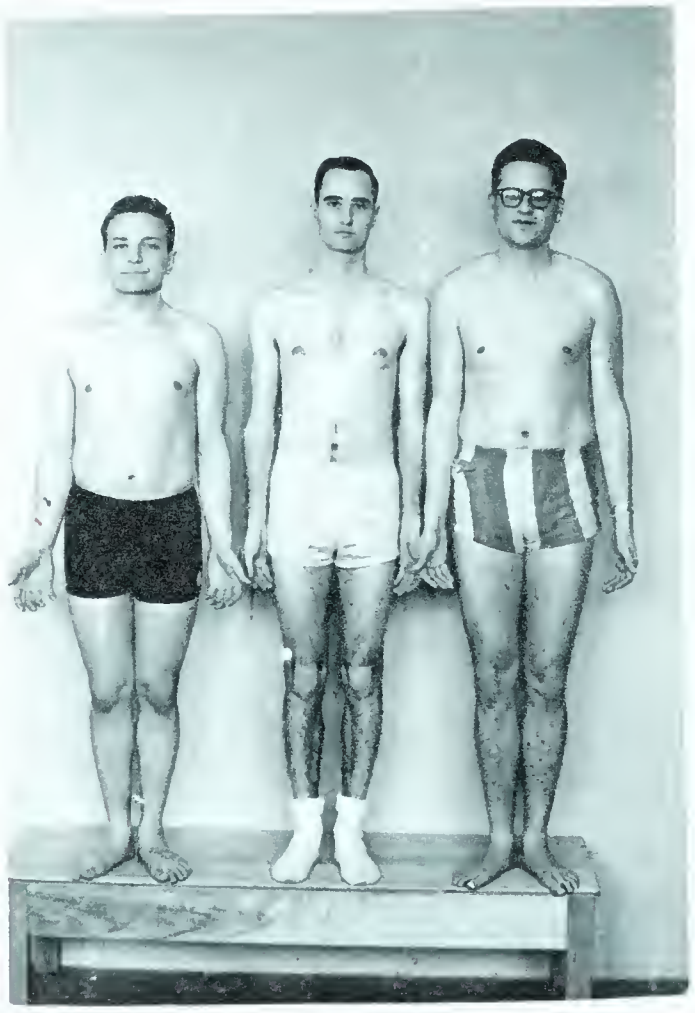
Final Day of Phase III

Front View of Subjects L.Y., M.B. and G.H. At Various Stages of Treatment



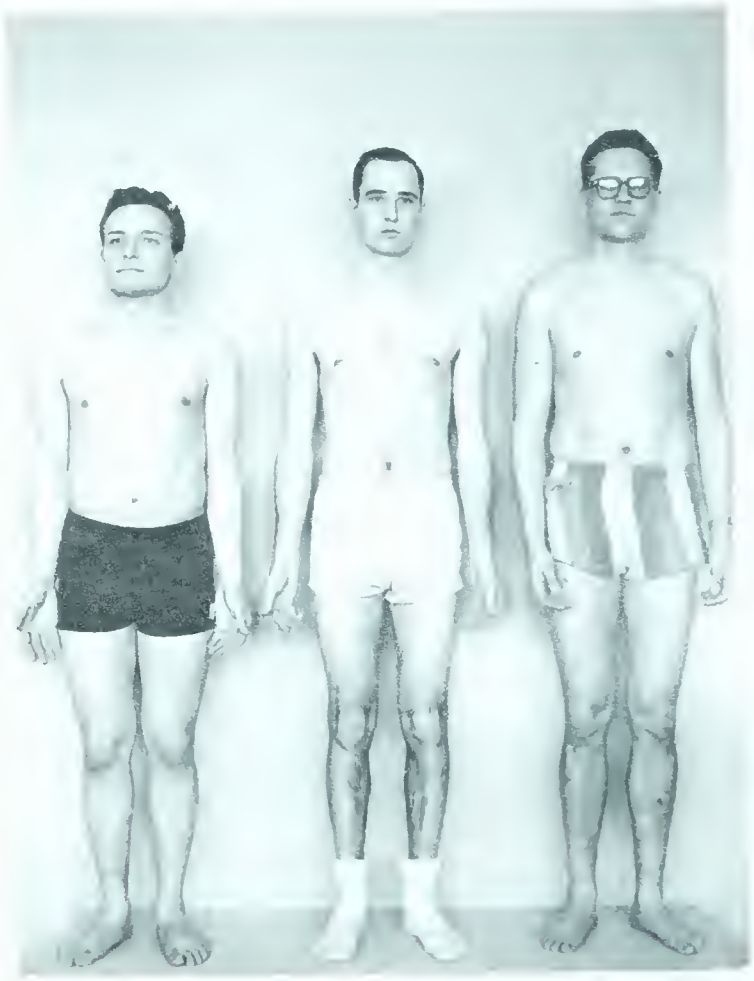
L.Y. M.B. G.H.

Initial Day of Phase I



L.Y. M.B. G.H.

Final Day of Phase I



L.Y. M.B. G.H.

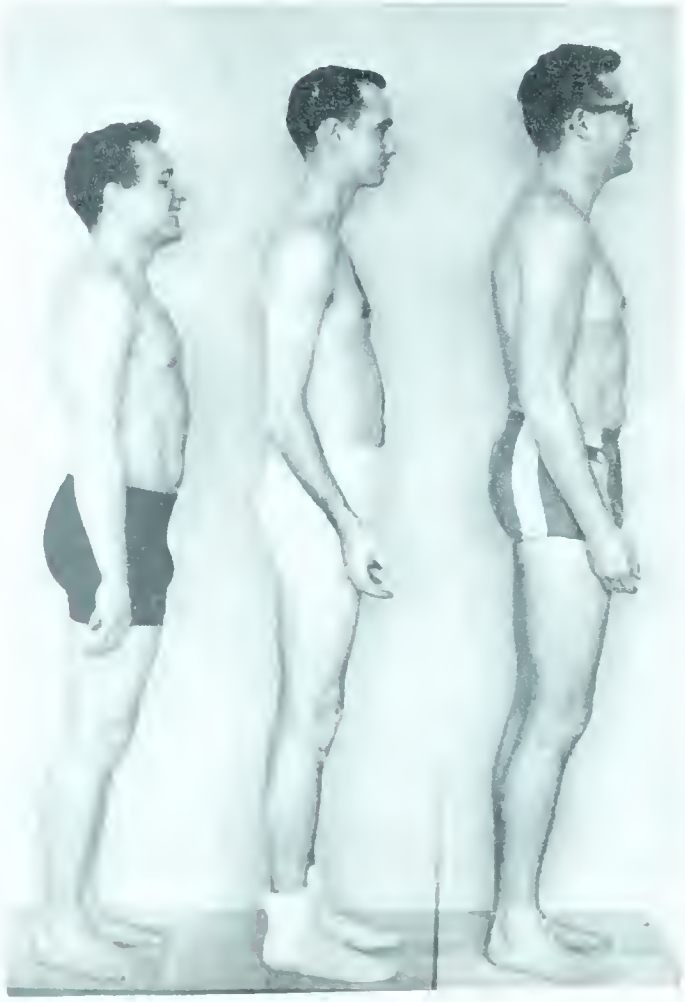
Final Day of Phase III

Side View of Subjects L.Y., M.B. and G.H. At Various Stages of Treatment



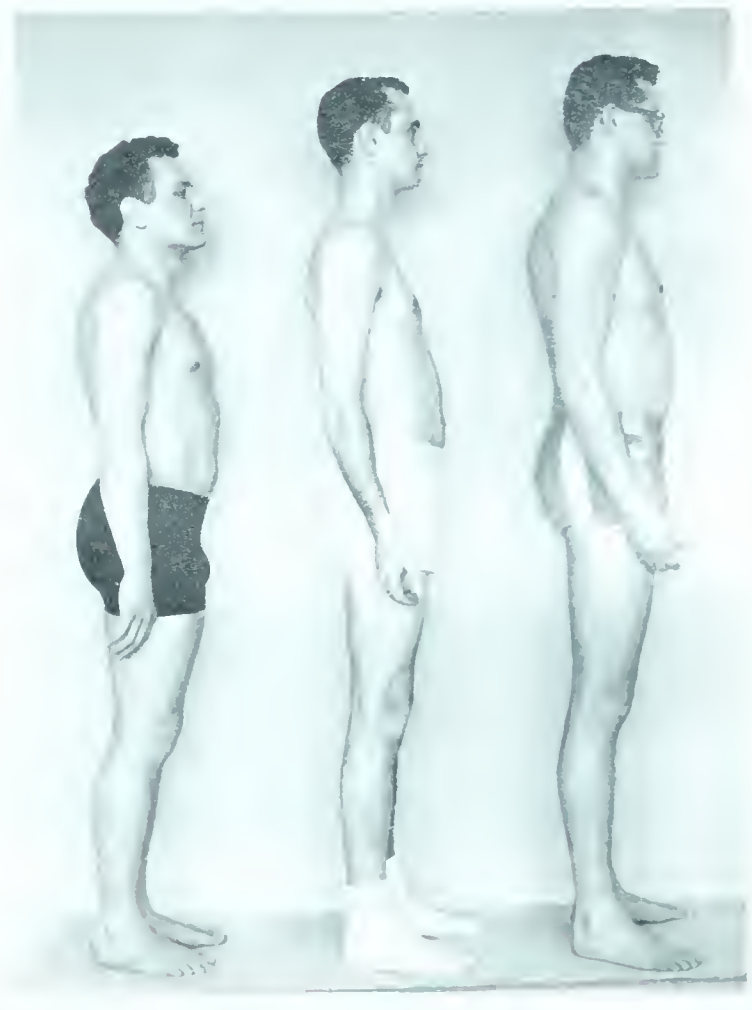
L.Y. M.B. G.H.

Initial Day of Phase I



L.Y. M.B. G.H.

Final Day of Phase I



L.Y. M.B. G.H.

Final Day of Phase III

Back View of Subjects L.Y., M.B. and G.H. At Various Stages of Treatment



L.Y. M.B. G.H.

Initial Day of Phase I



L.Y. M.B. G.H.

Final Day of Phase I



L.Y. M.B. G.H.

Final Day of Phase III

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